A STUDY ON EFFECT OF STONE COLUMN FOR SOIL STABILIZATION

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ABSTRACT

Stone column technique is an economical and environmental friendly method used to improve the load settlement of problematic soils. Stone columns are used for supporting flexible structures like oil storage tanks, embankments etc. This technique is suited for the betterment of soft soils such as silty sand, silts, clay and non-homogeneous fills. Lateral confinement occurs to the surrounding soil on installation of stone column. The amount and consequences of future liquefaction can be limited by the densification of soil with the help of vibrator and introducing stone in to the soil. This paper presents a review of previous studies on soil stabilization using stone column. Various parameters that are considered for the present review are diameter, l/d ratio, materials used and reinforcement provided. Design considerations of the stone column and its installation methods of stone column technique are also discussed in this paper.

Keyword: - *settlement, stone column, soft soil, stabilization, load capacity*

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1. INTRODUCTION

Coastal areas are covered with soft soil deposits having high compressibility and low shear strength. Pile foundations are good enough to meet the design requirements. But the point of economy, other ground improvement techniques are also preferred[1].Stone columns provide an economical method of support in fine grained and compressible soils for low rise buildings and structures like embankments, abutments, liquid storage tanks and factories [5]. Among various stabilization methods like vacuum pre-consolidation, soil cement columns and lime treatment, stone column technique is preferred due to the advantage of reduced settlements [17]. Slope stability of embankments on soft ground can also be improved using stone column [1].

Stone columns are vertical columnar elements filled with compacted and un-cemented stone fragments or sands or gravels formed below the ground level. Hence the presence of stone column creates a composite material which is stronger and stiffer than the original soil [14]. Load carrying capacity of a stone column is due to various reasons like frictional properties of granular material filled in the column, cohesion and frictional properties of surrounding soil of the column, characteristics of foundation transmitting stresses and the magnitude of lateral pressure developed in the surrounding soil mass[10]. Sometimes the columns may not derive significant load carrying capacity while installed in soft soil leading to low lateral confinement [17]. In such cases the load carrying capacity can be further improved by various techniques. An additional confinement to the stone column can be achieved by providing geosynthetic encasement to individual stone column [10]. Geosynthetic encasement is the technique of covering individual stone column using a suitable encasement material. The performance of fill embankment on very soft clay can be improved by the locked-in geosynthetic tension of encasement [15]. For the improvement of soft clay, fly ash aggregate can be effectively utilized as column material to reduce exploitation of conventional coarse aggregate [16].

Load deformation characteristic of the soil can be improved effectively using quarry dust, which is a waste product [4]. A stone column can withstand higher load on larger column with low settlement. Punching behavior is more for shorter column [11]. For a single stone column, L/B=2.5 have better bearing capacity. Spacing of horizontal reinforcement in the stone column has significant effect on the load carrying capacity of soil. Reinforcement placed at a spacing of D/2 shows better performance than D spacing [19]. For unreinforced column, bulging was found at half length of the column, whereas it was found just below the reinforced depth for reinforced column [12]. The experimental results are analyzed using the PLAXIS software. Finite- element analysis was performed using the Mohr- Coulomb's criterion and are compared with experimental results which showed good agreement between results [1].

2. LITERATURE REVIEW

Several researchers have studied and worked on the experimental, theoretical and field study on the behavior of the stone column. However, only very limited information is available on design procedure for a given situation.

J. T Shahu and Y. R Reddy (2011) [1] were conducted a series of load controlled model tests which were fully drained and their numerical simulations were studied. The tests were performed on a small scale physical model of floating column and various parameters such as area ratio, length of columns, relative density and moisture content of the column were evaluated. In the numerical analyses the clayey soil behavior is idealized by the modified Cam-clay model and the stone column by fully plastic Mohr- Coulomb model. The model prediction using finite element analyses was successful with reasonable accuracy.

A. P Ambily and Shilesh R Gandhi (2007) [3] done a detailed experimental study on the behavior of single as well as group of seven columns. Various parameters such as spacing between the columns, shear strength of soft clay and loading condition were considered. The tests were carried out either with single column loaded or entire equivalent area loaded. A 15 noded finite element analyses was done using PLAXIS software package to compare with experimental results. The results showed good agreement with each other. Design charts and a design procedure were suggested based on the results which ensure a required factor of safety and checks settlement.

Tandel Y. K, Solanki C H and Desai A K (2012) [2] carried out a small scale model test for short term loading condition on column foundation. They analyzed the bearing capacity and deformation behavior of geotextile coated sand column under static loading. For long term loading condition, they also have done numerical analyses. The geosynthetic reinforcement reduced the settlement of the soft ground and also the lateral bulging was minimized.

Marina Miranda and Almudena Da Costa (2016) [14] were conducted laboratory analysis of encased stone columns. The geotextile encasement provided satisfactory results by extra confinement. Drained triaxial tests were conducted to study the influence of encasement on the behavior of stone column. For this they tested gravel with two different densities and two different geotextiles were used. The results showed much improvement when gravel is encased with geotextile.

Aminaton Marto, Razieh Moradi, Farshad Helmi, Nima Latifi and Mohsen Oghabi (2013) [15] studied the behavior of un-encased versus geogrid encased stone column in soft clay. The authors introduced the assumptions, procedures and results of the analyses for the simulation. Various diameters were selected for the analyses and comparison of the behavior of the stone column. Finally they got a good agreement on comparison of the experimental results with the finite element software, PLAXIS.

S. Siva Gowri Prasad, Y. Harish and P. V. V. Satyanarayana (2015) [12] studied on the floating stone column which were reinforced by introducing lateral circular discs of geotextile sheets within the stone column. They used silica manganese slag as column material. Circular discs were placed at two different spacing over varying depth. The test results showed that stone columns reinforced with circular discs placed at D/2 spacing shows better performance

Ruben Aza-Gnandji and Denis Kalumba (2014) [10] investigated the behavior of rammed columns. Experimental results were compared with numerical analyses. The results showed that as the column diameter increases, the load carrying capacity also increases. Mohr coulomb and modified Drucker- Prager models were used for the idealization of the behavior of soil and column materials. Main failure mode was bulging.

S. R Lo, R. Zhang and J. Mak (2010) [16] done experimental study on geosynthetic encasement in enhancing performance of stone columns. From the findings it was clear that the stone column alone was not adequate in reducing the settlement. On incorporating geosynthetic encasement, they noticed a further reduction in the settlement. Also they analyzed the predicted performance of encased column with varying stiffness.

3. STONE COLUMN INSTALLATION METHODS

Installation of stone column is done by using either top or bottom feed systems, with or without jetted water. Most widely used methods are Vibro- Replacement (Wet, Top Feed Method) and Vibro- Displacement (Dry, Top and Bottom Feed Method).

The stone column construction can be carried out either by two methods i.e. displacement method or replacement method. Native soil is displaced laterally by a vibratory probe with the aid of compressed air in the displacement or dry method. This method is suitable only when the in situ soil is firm and the ground water level is low. It is represented in the figure 1 and figure 2. In the replacement method, native soil is replaced by stone columns. The holes are constructed by using a vibratory probe accompanied by a water jet as shown in the figure 3[13].

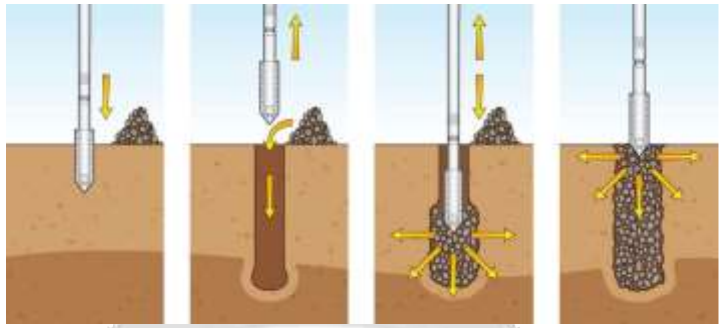

Fig 1: Dry – top - feed method process schematic (Taube, 2001).

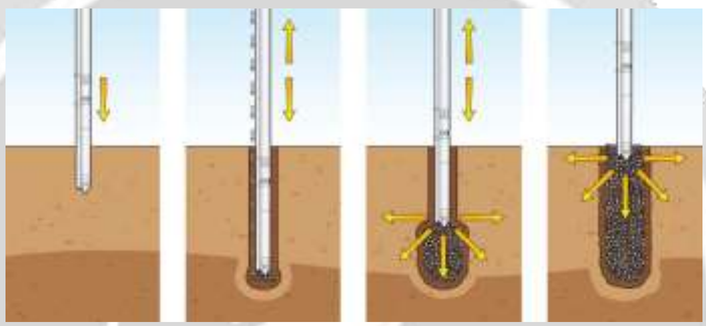

Fig 2: Dry – Bottom - feed method process schematic (Taube, 2001).

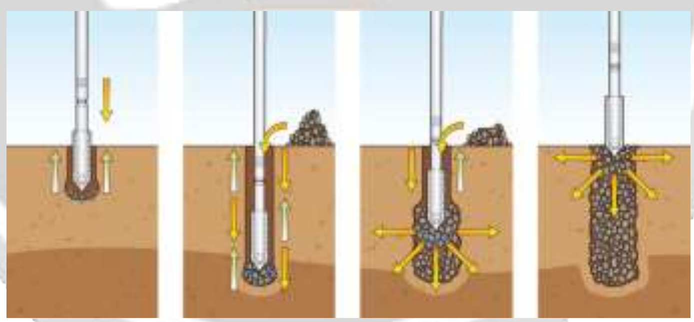

Figure 3: Wet - top - feed method process schematic (Taube, 2001).

4. DESIGN CONSIDERATIONS

First step in assessing the applicability of vibro-stone column for a particular site is to evaluate the performance of the unimproved ground. It is necessary to determine whether the stone columns will achieve the desired results in terms of settlement reduction, improve bearing capacity, densification etc.

Preliminary design of stone columns can be carried out as follows:

1) Using conventional settlement calculations, the settlement shall be estimated for the proposed loading conditions for unimproved ground.
2) To meet the design requirements, the reduction in settlement is determined. This reduction factor is the "settlement ratio" or "improvement factor", which is expressed as the ratio of the amount of settlement of the unimproved soils to the amount of settlement of the improved soils.
3) Determine whether the stone columns can provide the required reduction of settlement. Typically the settlement can be reduced by a factor between 2 and 3.
4) Area replacement ratio (stone column area divided by the tributary area of the stone column) is determined to provide the required reduction of settlement.
5) The stone column diameter, spacing and length are determined. Diameter and spacing is determined from contractor experience whereas the column length from the settlement calculations.
6) Load carrying capacity is assessed for the stone columns.

It is based on the contractor experience that the stone column diameter is predicted, which is a critical part of the design process. Stone column spacing can be simply calculated with a known required area replacement ratio and a prediction of the stone column diameter.

5. APPLICATIONS

Stone column behaves as vertical drains and speed ups the consolidation process. It increases the unit weight of soft soil by replacing with a stronger material. Stone columns can mitigate the potential for liquefaction and hence damage by providing drainage path which can prevent the buildup of high pore pressure.

6. ADVANTAGES

Stone columns are suitable for certain structure due to the following reasons:

- It can reduce the total and differential settlements.
- It reduces the liquefaction potential of cohesion less soil.
- It increases the stiffness.
- It improves the drainage conditions and environmental control.
- It improves the load capacity of the soil to make it possible to use shallow foundation on the soil.

7. LIMITATIONS

There is a chance for increase in settlement of the bed when used in sensitive clays due to the absence of lateral restraints. Because of the clogging of clay particles around the stone column there is a chance to reduce radial drainage. To overcome such situation, stone columns can be encased with geogrids/ geo-composites.

8. CONCLUSIONS

The stone column technique is an economical and effective method of soft soil stabilization. They are used to support embankments, large raft foundations and isolated footings.

- Stone columns can improve the load carrying capacity and reduces the settlement of the problematic soil.
- Construction can be started quickly due to the accelerated dissipation of excess pore water pressure in to the drainage formed by the stone columns.
- Before designing the stone column, thorough subsoil investigation should be done from in-situ test results and bore logs.

9. REFERENCE

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