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Experimental Studies on Ground Improvement Using Stone Column

Arvind I. Chaudhary[1], Manthan M. Jadhav[2], Shubham R. Bhoye[3]

Prof. Nivrutti Jadhav[4]

Arvind I. Chaudhary[1], Civil Department

Atma Malik Institute of Technology and Research, Mohili Shahapur

Manthan M. Jadhav[2], Civil Department

Atma Malik Institute of Technology and Research, Mohili Shahapur

Shubham R. Bhoye[3], Civil Department

Atma Malik Institute of Technology And Research, Mohili Shahapur

Project Guide : Prof. Nivrutti Jadhav[4], Civil Department

Atma Malik Institute of Technology and Research, Mohili Shahapur

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Abstract – This research examined the ground improvement technique for enhancing the load-bearing capacity and enhancing of weak or compressible soils. In this study, we focus on how we minimize the cost of ground improvement and make environment friendly solution for ground improvement. The research involves a review of the existing literature, including the Objectives, methodology, and case studies related to stone column implementation. Laboratory testing and field investigations are conducted to assess the geotechnical properties of the soil and the behavior of stone columns under different loading conditions. The project aims to provide insights into the geotechnical behavior of stone columns and their effectiveness in stabilizing weak soils. Furthermore, the study will explore the economic and environmental aspects of this ground improvement technique. The findings of this research are expected to contribute valuable knowledge to the field of geotechnical engineering, assisting engineers and construction professionals in making informed decisions regarding ground improvement methods.

Keywords : Ground Improvement, Stone Column, Soil Sample, cost effective, environment friendly, Load Bearing Capacity, Black Cotton Soil, Soil Stabilization.

1. INTRODUCTION

Stone Column is a technique used in civil engineering to improve and stabilize soils considered weak as soft clays or silts and loose sands, enabling the construction of highway facilities, storage tanks, embankments, bridge abutments and so on. Stone columns are typically constructed by drilling or vibrating into the ground. This process involves creating holes or cavities in the soil. Ground improvement, this technique can help consolidate loose or soft soils, making them more stable. Stone column ground improvement is a versatile and effective geotechnical solution used to enhance the load bearing capacity. Stone column technique has been developed very recently for improving bearing capacity and to enhance weak deposits like soft clays and loose sands. It has increasingly adopted in India. In this method a pre bore hole filled with granular material and compacted by a heavyweight rammer over the borehole.

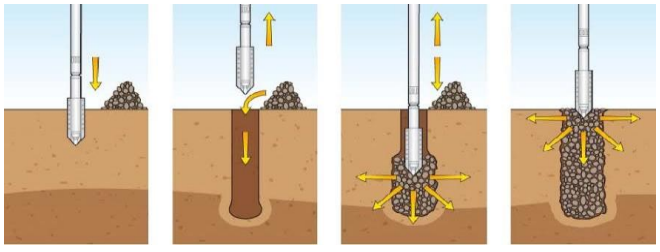


Fig No. 1 : Ground improvement using stone column.

1.1 Background

There are numerous ground improvement techniques are in practice to improve the properties of the ground. Stone column technique is a well-established technique and is best suited for improving soft clays, silts and also for loose sand deposits. The concept of Granular column was first adopted in France in 1830 to improve the properties of soil and later this is adopted all over the world to increase the bearing capacity, to reduce settlement, and also to increase the resistance to liquefaction (Barksdale and Bachus 1983, Alamgir et al 1996). Granular columns are constructed using an electric or hydraulic actuated vibrating probe. The probe was originally developed by Steuerman. The vibratory probe, essentially in cylindrical shape consists of a hydraulic or electric motor mounted within a cylindrical casing of 350mm-450mm in diameter and 2.0m – 4.5m in length. The motor powers a rotating eccentric weight which provides the lateral vibration and compaction. Granular columns are constructed using this vibrating probe either by wet process or dry process.

2. LITERATURE REVIEW

2.1 Behaviour of different materials for stone column construction

Kwa Sally Fahmi, E.S Kolosov, Mohammed Y. Fattah (2019) in their paper "Behaviour of different materials for stone column construction", the objective of paper was to study the Behaviour of different materials for stone column construction. They conducted Study of two different materials stone and sand in addition settlement versus load response was determine. Under the same loading condition, the weak soil was also analyzed and it has been found that the stones are the most effective material. Furthermore, experimental study on the behaviour of a group of four and eight columns was carried out through the finite element analysis with the PLAXIS 3D by using 16-Noded triangular elements. Through studying different pile materials which were used in the study it has been found that the most effective than sand for single column and group of columns. It was concluded that the inclusions of Piles considerably improve the low deformation properties of a clay soil. It has been found that stones are more effective than sand for single column and group of columns. The load capacity increases with decrease of spacing between columns.

2.2 Improvement of Bearing Capacity of Black Cotton Soil Using Stone Column

Harish C, Shashishekar T , Radhika K and Manjunath Itagi (2016), in their journal Improvement of Bearing Capacity of Black Cotton Soil Using Stone Column with and Without Encasement of Geosynthetics with the objective. To study the effect of quarry Dust column encased with geosynthetics in improving the strength characteristics of Black cotton soil. Laboratory model footing tests has been carried out on embedded, Single stone columns with and without encasement of geosynthetics of different grades In black cotton soil. Experiments are conducted to find out the effect of encasement and The performance of single column arrangement keeping diameter and length of the stone Column varying. The model tests are conducted in a steel cylindrical tank of diameter 250 mm and height of 300mm, the small-scale model footing tests are conducted on Unreinforced and reinforced black cotton soil. Unreinforced tests are carried out and Then reinforced with quarry dust column encasement are conducted. The parameters Studied in this study include the number of encased reinforcement (columns) for Embedded, depths.

2.3 Behaviour of Stone Columns Based on Experimental and FEM Analysis

A.P. Ambily & Shailesh Gandhi (2013), in their journal "Behaviour of Stone Columns Based on Experimental and FEM Analysis" with the objective: To study the Behaviour of Stone Columns Based on FEM analysis. They studied the behaviour of single column and group of seven columns is carried out by varying parameters like spacing between the columns, shear strength of soft clay, and loading condition. Laboratory tests are carried out on 100 mm diameter surrounded by soft clay of different clay.

The tests are either carried out either with an entire equivalent area loaded to estimate the stiffness of improved ground or only a column loaded to estimate the limiting axial capacity, During the group experiment's, the actual stress on column and clay were measured by fixing pressure cells on loading plate. Finite Element Analysis have been performed using 15-noded triangular elements with software PLAXIS.A drained analysis was carried out using Mohr's-Coulomb's criterion for soft clays, stones and sands. The numerical result from the FEM are compared with the experimental results which

showed good agreement between the results Columns arranged with spacing's more than 3 times the diameter of the column does not give any significant improvement. Stone columns spacing's should not be more than 3 times the diameter of the column.

2.4 Behaviour of stone column in Local Soft and loose layered Soil

Pradip Das & Dr. Sujit Pal (2013) published their research paper on "A study of the behaviour of stone column in Local Soft and loose layered Soil" The objective of paper was to study of the behaviour of stone column in Local Soft and loose layered Soil. Stone columns are found effective, feasible and economical to improving the soft and loose layered soil. Stone columns increase the unit weight and the bearing capacity of soil. It can densify the surrounding soil during construction. The improvement of a soft soil by stone columns is due to different sizes of aggregate (size between 2 to 10 mm) in the soft soil. This paper presents the utilization of stone column to improve the load

2.5 Suitability of different Materials for stone column construction

Dipti Sarin Isaac and Girish M. S.(2009) published paper on Suitability of different materials for stone column construction to study the suitability of different materials of stone column construction. The influence of column material in the performance of stone column is studied through laboratory experiments on model stone columns installed in clay. Five reinforcement materials were studied: stones, gravel, river sand, sea sand and quarry dust. Load versus settlement response was determined. The unreinforced soil under the same loading condition was analyzed. Quarry dust, though a waste product is effective in improving the load deformation characteristics of the soil used. Experimental study on behaviour of group of three columns and seven columns was also conducted. A finite element analysis using 15-noded triangular elements with the software package PLAXIS was also carried out. In their research the concluded that the grain size of the stone column material is one of the main controlling parameters in the design of stone columns. There is no significant difference in the load deformation behaviour of soil with stone columns using river sand and sea sand. It is found that stones are the most effective stone column material. Adopt stone as a granular material for construction.

2.6 Load settlement Behaviour of granular pile in black cotton soil

Siddharth Arora, Rakesh Kumar & PK Jain (2008), "Load - settlement behaviour of granular pile in Black cotton soil" with the objective to study Load - settlement behaviour of granular pile in Black cotton soil. The paper discusses the results of study conducted on floating granular piles constructed in soft black cotton soil. The soil beds were prepared in a model tank of diameter173 mm and height 605 mm. The granular pile of diameter55mm was constructed at the centre of soil bed using crushed stone chips as the pile material. The load test was conducted on the granular pile. The length to diameter ratio (L/d ratio) of the pile was varied, from 1 to 11 with an interval of two, and the effect of pile length on load carrying capacity was studied. Further, to observe the effect of encasement of pile material, it was wrapped by geo grid and the load test was conducted. The test results show that the ultimate load carrying capacity, Qult of the granular pile increases as L/d ratio increases in both the cases i.e., without and with geo grid encasement. The increasing trend of Qult with L/d is observed continuing for the maximum L/d ratio i.e. 11, for the granular pile tested in the study.

2.7 Behaviour of Encased stone column and conventional stone column

Malarvizhi and Ilamparuthi (2008) in their journal, "Comparative study on the behaviour of Encased stone column and conventional stone column" with the objective to have a Comparative study on the behaviour of Encased stone column and conventional stone column. The behaviour of the encased stone column stabilized bed is experimentally investigated and analyzed numerically. In the numerical analysis, material behaviour is simulated using Soft Soil, Mohr Coulomb and Geogrid models for clay, stone material and encasement respectively and is validated with experimental results. The parametric study carried out on varying the LWD ratio (L = length of the column; D = diameter of the column) of column, stiffness of geogrid and angle of internal friction of stone material gives a better understanding of the physical performance of the encased stone column stabilized clay bed. It increases bearing capacity and reduce total and deferential settlements of structures constructed on soft clay. Stone columns also act as vertical drains, thus speeding up the process of consolidation. The settlement of stabilized bed is not reduced in many situations for want of adequate lateral restraint. Encasing the stone column with a geo grid enhances the bearing capacity and reduces the settlement. Stone columns, one of the most commonly used soil improvement techniques, have been

utilized. Encased stone column is better than un-encased stone columns.

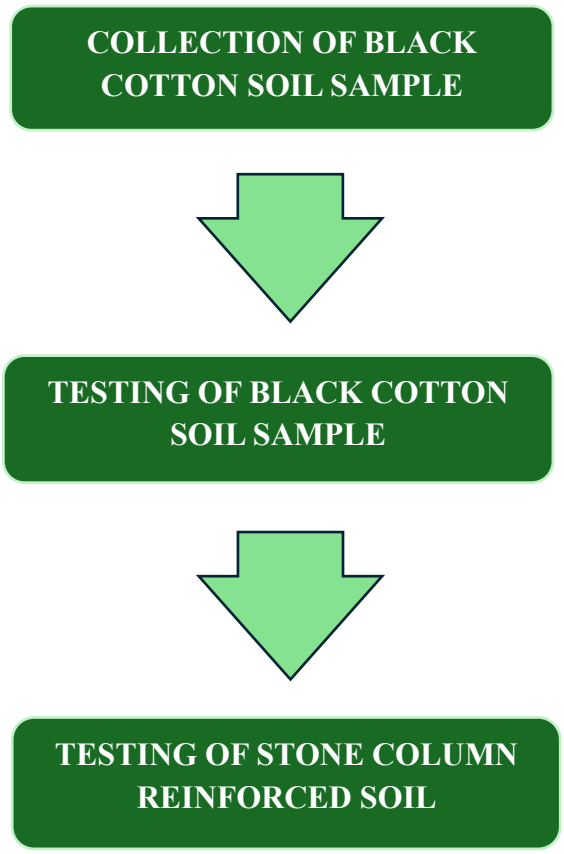
2.8 Solutions for consolidation rates of stone column reinforced.

J. Han and S.L. Ye (2002), published paper on "A Theoretical Solution for Consolidation Rates of Stone Column Reinforced. (Foundations Accounting for Smear and Well Resistance Effects.)" with the objective to study "A Theoretical Solution for Consolidation Rates of Stone Column Reinforced". A simplified theoretical closed-form solution has been developed in this article for computing the rate of consolidation accounting for smear and well resistance effects. The parametric study indicates that the reduction of the permeability of the stone column and/or the smeared zone and/or the stress concentration ratio decreases the rate of consolidation. Compared with other solutions for drain wells or the authors' previous solution for stone columns without smear and well resistance effects, the proposed solution in this article has addressed more comprehensive issues related to the consolidation rates of stone column reinforced foundations.

2.9 Investigated the efficiency of general stone Columns and lime column

Poorooshasb and Meyerhof (1997) investigated the efficiency of general stone Columns and lime columns in reduction in settlement of soft soils. The effect of several Factors like column spacing, properties of soil, properties of stone chips, in situ stress And the depth of firm base from the tip of the column was studied

3. METHODOLOGY



3.1 Collection of Black Cotton Soil

The availability of land for the development of commercial, industrial and transportation etc. are scarce particularly in urban areas. This necessitated the use of land, which has weak strata. Due to ever increasing necessity of land, the need to use marginal sites with poor engineering properties has become mandatory. The use of stone columns has proved to be an economical and technically viable ground improvement technique for construction on soft soils. The stone columns are usually designed for carrying vertical loads from the structures. Ground improvement is the modification of foundation soils or project earth structures to provide better performance under operational loading conditions. Ground improvement methods are used increasingly for new projects to allow utilization of sites with poor subsurface conditions and to allow design and construction of needed projects despite poor subsurface conditions which formerly would have rendered the project economically unjustifiable or technically not feasible.

Materials Used : Black Cotton Soil Sample.

The required amount of soil is collected from trail pits at a depth of 2m below the ground level since the top soil is likely to contain organic matter and other foreign materials. Sufficient care has been exercised to see that the collected soil samples are fairly homogenous. and stored in steel drums for further testing. Soil will be collected near thane district regions with availability of black cotton soil.

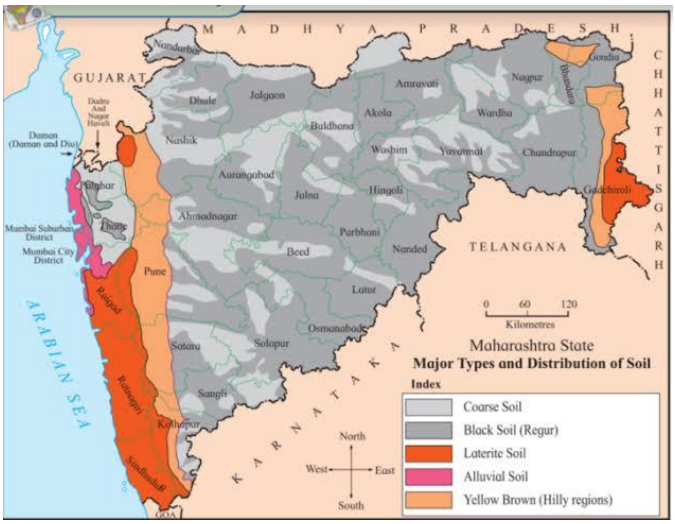


Fig No. 2 : Maharashtra State Distribution of Soil.

3.2 Testing To be Conducted On Black Cotton Soil Sample

- Moisture Content
- Liquid Limit
- Plastic Limit
- Specific Gravity

Moisture Content - This test was conducted in college lab for which IS 2720 part 2 (1973) was used, a series of three samples of different weights of 89, 75 and 105 gm respectively were conducted and average value was considered as final one. Following are the test results obtained after testing the soil. The average water content in the soil was found to be 8.53.

Liquid Limit - The liquid limit of soil is a property that indicates the moisture content at which the soil changes from a plastic state to a liquid state. In other words, it is the minimum moisture content at which the soil behaves as a liquid under the influence of a small shearing force. The liquid limit is determined by performing a standardized laboratory test called the Casagrande's method, which involves measuring the number of blows required to close a standard groove in the soil sample. The liquid limit is expressed as a percentage of the weight of the dry soil. The liquid limit is the moisture content at which the groove formed by a standard tool into the sample of soil taken in the standard cup, closes for 12 mm on being given 25 blows in a standard manner. The test is conducted, conforming to IS: 2720: 1985 part 5.

Plastic Limit - The plastic limit of soil is a property that indicates the moisture content at which the soil changes from a plastic state to a semi-solid state. In other words, it is the minimum moisture content at which the soil can be rolled into a thread of 3mm diameter without breaking. The plastic limit is determined by performing a standardized laboratory test called the rolling method, which involves rolling a soil sample into a thread of 3mm diameter. The plastic limit is expressed as a percentage of the weight of the dry soil.

The difference between the liquid limit and the plastic limit of soil is an important parameter known as the plasticity index, which is used to classify soils into different groups based on their engineering properties. This test was also conducted at our college which was conducted, conforming to IS: 2720:1985 part 5.

Plastic limit in the black cotton soil was found to be 21.16

Specific Gravity - The specific gravity of soil is a measure of the density of a soil sample relative to the density of water. It is defined as the ratio of the mass of a given volume of soil solids to the mass of an equal volume of water at a specified temperature. The specific gravity of soil is an important property that is used to determine the void ratio, porosity, and degree of saturation of a soil sample.

The specific gravity of soil can be determined by performing a standardized laboratory test called the pycnometer method. In this method, a known mass of dry soil is placed in a pycnometer, which is then filled with water to a known volume. The pycnometer is then weighed, and the specific gravity of the soil is calculated as the ratio of the mass of the dry soil to the mass of an equal volume of water.

The specific gravity of soil Is typically reported as a dimensionless number between 2.0 and 3.0, depending on the type of soil. Soils with high specific gravity values are typically denser and have lower porosity and void ratios than soils with low specific gravity values. The specific gravity of soil is an important parameter in geotechnical

engineering, as it can be used to calculate the weight-volume relationships of soil samples and to estimate their compressibility and shear strength. This test conforms to IS 2720 (Part III) – 1980.The average specific gravity was found to be 2.83.

4. EXPECTED CONCLUSION

Many of the properties of soil can be enhanced by the application of the stone column. The settlement of soil will considerably reduced after installation of stone column. Generally, black cotton soil is mostly seen in agricultural fields specially in Maharashtra hence light weight structures can be constructed on such soils. As per the tests carried out, it was found out that black soil is weaker compared to red soil and stone column can significantly increase the strength of loose and permeable soil. For, Stone Column to take maximum load & serve at its best it should have optimum diameter and length which varies from soil to soil. The Cost of this ground improvement using stone column will minimized. Intensive excavation will be reduced in this ground improvement using stone column method.

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BIOGRAPHIES

First Author : Arvind Indrajit Chaudhary
Pursuing Bachelor's of Engineering In University of Mumbai.
Atma Malik Institute of Technology and Research, Mohili Shahapur.
Diploma in civil engineering 2021 [MSBTE]
Maharashtra State Board of Technical Education.
Vishwatmak Om Gurudev College of Engineering.