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Use of Geosynthetic Encasement in Stone Column for Ground Improvement

Swapnil S Sanap[1], Krishna S Ingale[2], Bhojraj S Patil[3], Vaibhav M Chaudhary[4], Prof. Puneet Jain[5]
[1, 2, 3, 4]*BE Student,* [5]*Assistant Professor, Sandip Foundation's Sandip Institute of Engineering & Management, Mahiravani,Nashik, India*

Abstract: Ground improvement is an important requirement in today's construction industry as landreclamation is becoming increasingly popular. The stone column technique is a very efficient method of improving the strength parameters of soil like bearing capacity and reducing consolidation settlement.
Soil reinforcement can be an ideal solution for the improvement of clay. Out of other conventional methods, stone columns are effectively being used for ground improvement, particularly for the construction of flexible structures such as road embankments, oil storage tanks, etc on soft soils. It offers a much more economical and sustainable alternative to piling and deep foundation solutions. This report investigates thequalitative and quantitative improvement of individual load capacity of stone columns by varying the diameterof stone columns through laboratory model tests conducted on stone columns installed in clay beds prepared in controlled conditions in a large-scale testing tank. The results from the load tests indicated the performance of a smaller diameter stone column is superior to that of a bigger diameter stone column and the stone grit used to Promote the vertical drainage function of the column by acting as a good filter.
Keywords: Stone column, Ground improvement, Geosynthetics, Geotextile, etc.

I. INTRODUCTION

About 20% area of India is covered by black cotton soil which is predominantly found in Gujrat, Maharashtra, Madhya Pradesh, south U.P, Parts of Karnataka, Andhra Pradesh, and Tamil Nadu. In the recent past, a large number of ports and industries are being built. In addition, the availability of land for the development of commercial, housing, industrial and transportation, infrastructure, etc. are scarce, particularly in urban areas. This necessitated the use of land, which has weak strata, wherein the geotechnical engineers are challenged by the presence of different problematic soils with varied engineering characteristics. Many of these areas are covered with thick soft clay deposits, with verylow shear strength and high compressibility. There are several methods available to improve ground conditions such as stone columns, jet grouting, compaction grouting, short pile, dynamic compaction, lime stabilization, etc. Before using any of these methods, it is required to know the ground improvement in detail. In simple words-ground improvement can be defined as “the process of enhancing the quality of the soil."The techniques for soil improvement have been changing during the last three decades. The reinforcement of ground by tension-resistant elements can be applied for improvement in weak strata. This reinforcement can be provided with stone columns. Stone columns, also known as granular piles have been used to a large extent for several applications. Stone columns essentially increase the bearing capacity of soft soils. Therefore, ground reinforcement by stone columns solves the problems of the soft soil by providing the advantage of reduced settlement and accelerated consolidation process. In the case of a group of sand columns, Bulging was found the primary mode of failure. This drawback can be overcome by wrapping the individual sand columns with a suitable geosynthetic. The geosynthetic encasement helps in the easy formation of the sand column and improves thestrength and stiffness of the columns. By reinforcing sand columns with Geosynthetic, the ultimate bearing capacity of that column can be increased to a considerable amount. Thus the geosynthetic encased sand column is the technique for reinforcement to improve the loading capacity of the ground.

II. LITERATURE REVIEW

1) Uttam Kumar(2013), has conducted a study on the "Effect of geosynthetic Encasement on sand columnin soft soil”. This paper investigates the improvement in the loading capacity of sand columns in a square pattern after all-around encasement by different types of geosynthetic. This paper represents the load response of different diameters of the encased sand columns in the group load test. The effect of the encasement length of the sand column is also investigated. The results can be useful to save thecost, effort, and time for the installation of stone columns

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2) S. Murugesan & K.Rajagopal(2009), have conducted a study on “Experimental and Numericalinvestigations on the behavior of geosynthetic encased stone columns". This paper explains thelaboratory model tests performed on the stone columns with and without geosynthetic encasement and subsequently the numerical simulation of the results using the Finite Element Method.
3) Joel Gniel and Abdelmalek Bouazza (2009)have conducted a study on "Predicted site behavior of geogrid encased stone columns”. This paper discusses laboratory testing, numerical study, and possible practical applications for geogrid-encased columns. Results from small-scale testing and a detailed numerical study have indicated that stone columns fully encased with geogrid could extend the ground improvement technique to extremely soft soils. The numerical study was calibrated to a deposit ofsoft, compressible clay (Coode Island Silt) and indicated that settlement reductions of up to 90% could be achieved for fully encased columns when compared to untreated settlements. This performance is similar to other methods of ground. improvement including soil mixing. Furthermore, fully-encased or partially-encased columns could be used on stone-column projects to reduce the number of stone columns used, reduce the settlement, or tailor settlement to design requirements.
4) Eiman Fathi & Reza Mohtasham(2016), have conducted a study on "Numerical Analysis of the Reinforced Stone Column by Geosynthetic on Stability of Embankment”. This paper represents the influence of a reinforced stone column by Geosynthetic in comparison to when an ordinary stone column is used, which has been investigated. The two-dimensional dynamic finite element program (PLAXIS8.2) is used to carry out all the numerical experiments. In this study, for achieving optimum design, by analyzing the Primary Components such as Geometric parameters, stiffness of materials, stiffness of reinforcements, and shear strength of the soft soil, some useful and technical comments have been presented.
5) Wu and Hong (2008), conducted a series of laboratory tests on the granular columns with the horizontally laminated reinforcing sheets to verify the analytical procedure proposed to analyze the column expansion. Triaxial compression tests were carried out on cylindrical specimens of 14cm height and 7cm diameter. The granular column material was sand with the internal frictional angle of 36.81º.Four layers of geotextile layer were installed at an equal spacing which is the double distancefrom the end of the column as shown in Figure 16. The effect of the reinforcement stiffness, reinforcement strength, granular column radius, and spacing of the reinforcing sheets was investigated. From the investigation, it was found that the increase in the inclusions stiffness can lower the axial strain of the granular column. Smaller spacing of the reinforced granular column increases the stiffness of granular columns for the same radius/spacing ratio.
6) Puneet Jain et.al (2020), discussed to make the nation relate to India, road frameworks structure the techniques for the nation. Strands can be steel fibers, glass strands, trademark strands, produced fibers, etc. The addition of fibers to a solid makes it a consistent and isotropic material. Roadways are used for generous traffic stacks all through the world remaining to its better and monetarily getting execution. Steel fiber strengthened black-tops are the new kind of pavements that are expanding a huge amount of importance in current events. These black tops use fibers in the covering of pavements. Steel strands are an instance of fiber used truly coming to fruition of such black-tops. Steel strands are known to be serious and impenetrable to atmospheric conditions. These properties make steel strands significant in the improvement of structures. This paper deals with an exploratory assessment of the properties of concrete by solidifying FRC materials in the strong mix. The nature of the black-top can be extended while advancing by including more steel strands. The modifications in properties of strong when steel strands are used in concrete in its common structure and in the wake of changing its properties by displaced by steel fibers and adjusted steel fibers by 1 to 4 % in M40 assessment of concrete. Test results on Compressive Strength, Split Tensile Strength, and Flexural Strength.

A. *Objectives*

1) Identification of suitable geotextile encasement material.
2) Evaluation of functional advantages for geotextile-based encasement in stone columnperformance.
3) Estimation of improvement in mechanical strength of stone column encased geotextile.

B. *Research Gap*

The use of Geotextile and Geosynthetic Encasement In Stone Column For Ground Improvement has not been explored.

III. RESEARCH METHODOLOGY

A. *Experimental Work*

The experimental work consisted of twoparts.
Part 1;- aimed to determine the physical and mechanical properties of the soft soil and stone columnmaterials.

Part 2;- included experiments performed on model embankments resting on soft soil providing strengthby stone column.
Soft soil was brought from a depth of 5 m from a site near the podar international school pathardi phata Nashik. The soil was subjected to routine laboratory tests to determine its properties, including Atterberglimits (liquid and plastic limits) according to IS: 2720 (part-V) 1985, specific gravity according to IS:2720 (Part 3,section-1)1980 and Standard proctor test according to IS 2720-PART VII-1980. Table 1 shows the physical properties of soil.

B. Material Properties

Property	Value
1. Liquid limit (%)	50.5
2. Plastic limit (%)	24
3. plasticity index	26.5
4. Specific gravity	2.6
5. Maximum dry unit weight (KN/m3)	15
6. Optimum moisture content(%)	19.56

IV. EXPERIMENTAL WORK

A. Model Design and Manufacture

To study the behavior of soft soil reinforced by stone columns underneath an embankment, an experimental setup with an approximate scale of 1/10 to 1/20of the prototype was designed and manufactured to achieve this goal. The setup consisted of a plastic tank, loading frame, hydraulic jack for application of load, dial gauge for measurement of settlement, and proving ring for measuring the load. The plastic tank is used to host the bed of soil and its accessories the internal dimensions of the tank were 1000mm diameter, and 800mm depth The tank was sufficiently rigidand exhibited no lateral deformation during the soil and test. Fig.1 shows the experimental tank. Fig2 shows the arrangement of the loading frame with hydraulic jack, proving ring, and dial gauge. The loading frame consisted of two steel rods welded together with a steel plate at the bottom and the top steelplate was movable for the arrangement of fixing the jack.

Fig.3.3

Fig.3.4

B. Preparation of Soil

The soil was placed in a tank in such a way that the density of the soil was matched with the density of the soil on site. The soil was placed in a layer of 15 cm and each layer was leveled gently using a 50 x 150mm wooden tamper. This process was continued throughout the 5 layers until a depth of 750 mm wasreached in a tank.

C. Design And Installation Of Stone Column

1) *Stone Column Diameter:* Installation of stone columns in soft cohesive soils is a self-compensating process that is softer the soil, the bigger the diameter of the stone column formed. Due to the lateral displacement of stones during vibrations/ramming, the completed diameter of the hole is always greater than the initial diameter of the probe or the casing. Considering a stone column diameter of 40mm,60mm, and 80mm.
2) *The Pattern of the Stone column:* Stone columns should be installed preferably in an equilateral triangular pattern which gives the densest packing although a square pattern may also be used. Fig7 shows a patternof the stone column
3) *Spacing of stone column:* The design of stone columns should be site-specific and no precise guidelines can be given on the maximum and the minimum column spacing. However, the column spacing may broadly range from 2 to 3 depending upon the site conditions, loading pattern, column factors, installation technique, settlement tolerances, etc. For large projects, it is desirable to carry out field trials to determine the most optimum spacing of stone columns taking into consideration the required bearing capacity of the soil and permissible settlement of the foundation. Consider a spacing ofstone column = 2.5 times the diameter of stone column S =100mm, 150mm & 200mm for a stone column having diameter 40mm, 60mm & 80mm respectively.
4) *Equivalent Diameter:* The tributary area of the soil surrounding each stone column formsa regular hexagon around the column. It may be closely approximated by an equivalent circular areahaving the same total area.

   The equivalent circle has an effective diameter (De) which is given by the following equation: De = 1.05 S for an equilateral triangular pattern, and = 1.13 S for a square pattern

Where,

S = spacing of the stone columns.

The resulting equivalent cylinder of composite ground with a diameter enclosing the tributary soil and one stone column is known as the unit cell.

De(40mm) = 1.05 x 100 = 105mm

De(60mm) = 1.05 x 150 = 157.5mm ~ 160mmDe(80mm) = 1.05 x 200 = 210mm

Installation of the stone column The correct position of the stone columns was marked according to the proposed configuration patterns of stone columns given in IS15284(Part 1):2003. A hollow steel pipe with an external diameter of 10.5cm, 16cm, and 21cm was pushed down the bed to the specific depth (ie. l/d ratio= 10). After that, the casing was removed. The stones were placed in layered and compacted byusing the tamping rod. Fig9 shows the installation of the stone column.

V. CONCLUSION

1) Based on the above result and discussion following points were drawn.
2) The performance of smaller-diameter stone columns is superior to that of bigger-diameter sandcolumns.
3) The stone column was the best alternative to pile foundation, as well as a foundation as the cost of grit was minimum.
4) Promoting the vertical drainage function of a column by acting as the good filter
5) The mode of failure for an embankment model resting on untreated, very soft soil was close to localshear failure, whereas the mode gradually change towards the general shear failure when using stone columns.

VI. FUTURE SCOPES

1) Encasing can be provided for additional lateral confinement of the stone column and prevent the cloggingof the stone column.
2) The economical construction waste material can be used as an alternative to stone aggregates and helpsin the reduction of the overall cost of the project.

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