Bearing Capacity Improvement of Soil using Geosynthetic Reinforced Granular Columns

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Abstract - Strengthening poor soil layers is a common goal of the stone column technique of ground development. Cohesive soils' ability to support stone columns is virtually increased. Using columns made of crushed coconut shell that are both horizontally and vertically strengthened, the study examines the bearing capability of soft soil. A tank was used to conduct a number of laboratory plate load tests to examine how individual and groupings of vertically and horizontally reinforced columns behave. In this work, coir geosynthetics, a natural geosynthetic, and crushed coconut shell (CCS), a waste product, are used as reinforcement and filler materials, respectively. A 5 cm diameter column made of crushed coconut shells that was erected in soft soil was used for the tests. By covering the column in geotextile, the vertical reinforcement is accomplished. Geotextile is wrapped around the column to give it vertical reinforcement, and geogrid is placed inside the column at intervals of D, D/2, and D/4 to provide horizontal reinforcement. A comparison of single and collective columns made of crushed coconut shells that are vertically and horizontally reinforced in soil is done. Geosynthetic-reinforced CCS columns could increase the soil's ability to support weight. A variety of potential site applications are made possible by this range of performance for the geosynthetically reinforced crushed coconut shell columns technology.

Keywords - Granular Column, Crushed Coconut Shell, Plate Load Test, Reinforcement.

I. INTRODUCTION

Inadequate settling or stability problems are frequently present when erecting structures like buildings, storage tanks, warehouses, and so forth on brittle soils. These problems can be diminished using a variety of soil improvement techniques. One of the most efficient ways to strengthen brittle soils is to use granular columns. Under the right circumstances, stone columns can be a useful technique for (1) boosting bearing capacity and slope stability, (2) lowering settlement, (3) quickening consolidation, and (4) lowering the risk of liquefaction.

The stabilisation of current slopes may make considerable use of granular columns. A bendy shape that can be fairly realistic is produced by using granular columns to reinforce earthen buildings. The pros and cons of each method should be carefully considered when comparing granular columns to other layout options for a given application. Granular column installation is more of an art than a true science; as a result, it requires careful site supervision and a skilled contractor.

The soil’s bearing ability is improved when crushed coconut shell is used as filler in granular columns. The goal of the current study is to decide how well single and group floating column’s function when geosynthetic material is used as infill and as reinforcement in both the horizontal and vertical planes.

II. LITERATURE REVIEW

Soft clay's resilience is increased with a single 10 mm column of crushed coconut shell (CCS) as examined by Hasan et al. [10] in 2019. For four batches of kaolin, tests were done on the mechanical and physical features of the material, the CCS column, and the shear strength parameters. Three different column penetration ratios of 0.60, 0.80, and 1.00 were considered together with the CCS column's heights of 60, 80, and 100 mm. A kaolin sample had undergone 16 unconfined compression tests with measurements of 100 mm in height and 50 mm in diameter. For an area displacement ratio of 4% and consideration of the column penetration ratios of 0.60, 0.80, and 1.00, the shear strength increase embedded in CCS columns is 19.02, 34.76, and 24.34%, respectively. According to the data, peak column strength is independent of column maximum height but is dependent on shear strength increment.

Single stone columns' ability to support loads was explored by Hamidi et al. [9] in 2018. Tests were performed using a variety of columns reinforced with steel fibres as well as columns made of gravel in a variety of forms and particle distributions. The granular columns that were examined had diameters of 63 and 92 mm and a length-diameter ratio of 5. The test results with various geotextile shapes were examined, and it was discovered that employing granular columns' ability to support weight is improved by the mattress, geotextile, and steel fibre reinforcement. In comparison to a regular granular column, the encased granular column's weight carrying capacity increases as the diameter does.

Spoorthi et al. [16] (2019) investigated how a geosynthetic stone column could increase its bearing capacity. The material utilised was a granular fill with a 12 mm diameter and a 50 mm stone column. The geotextile covering a granular column had a length-diameter ratio of 4. There were three different space-to-diameter ratios used: 2, 3, and 4. S/D= 2 were found to get the best results. Additionally, when compared to a stone column without encasing, it was found that the geotextile-encased stone column could support more weight. That is, the capacity of a granular column to support weight with an encasement was 75.43 percent, and the load-bearing capability of a granular column lacking an encasement was 67.4%.

Geosynthetic reinforced stone columns were the subject of a sample test by Ali et al. [2] in 2012. The test used both reinforced and unreinforced, short, floating, fully penetrating single columns. Different methods of reinforcement and their effects on the composite ground's failure stress were assessed. The different failure modes caused by the various configurations and types of reinforcements can be seen by comparing evaluations of columns of various shapes. The end-bearing stone column encasement was determined to be the best technique from the comparison. The encasement for the floating stone columns and the horizontal strip reinforcement work similarly, with no difference in terms of effectiveness. For both types of reinforcement on end-bearing columns, geogrid is the best type of geosynthetic to use. However, for floating columns, geotextile as the encasing material and geogrid as the horizontal strip are optimal.

Prasad et al. [13] (2016) investigated how stone columns enhanced with spherical geogrid discs could increase the performance of soft soils. The two spacings D and D/2 were taken into consideration as the variable parameters. It was discovered that a granular column submerged in clayey soil enhanced the ultimate bearing capacity by roughly 117%. The load carrying capacity was enhanced by 16% and 41%, respectively, when the circular geogrid reinforcement was positioned at D and D/2 spacing. By adding geogrid reinforcement, the stone column's settling was also reduced. The soft soil's potential to support loads was enhanced by lateral reinforcement using geogrid discs, and it varies depending upon the spacing of reinforcement.

Geosynthetic-encased granular columns' bearing capacity was researched by Ghazavi et al. [6] in 2012. Granular columns with diameters of 60, 80, and 100 mm were examined in a laboratory; the length- diameter ratio was 5. The experiments were performed on a geotextile-reinforced stone column that was both exposed and enclosed. In addition to the tests mentioned above, a test on a group of 60mm diameter stone columns was performed to determine the enclosed stone column's ability to support a load. After executing all of the tests, it was discovered that the vertically encased granular column's bearing capacity was greater than that of a regular granular column. The granular column's bearing capacity grows along with its length and strength as it is vertically encased. Tests on groups of vertically enclosed granular columns and groups of regular granular columns show that the vertically encased stone column groups have a greater capacity to support loads.

In their 2010 study, Murugesan and Rajagopal [12] examined a geosynthetic-encased granular column's behaviour both individually and collectively. Geosynthetics-encased stone columns served as the subject of model experiments. In a large-scale testing tank, stone columns were put on a clay substrate that had been prepared under regulated conditions. Stone columns were tested under load individually and in groups, both with and without encasing. On a stone column covered in various geosynthetics, tests were run. The end result was a noticeable increase in the granular column's ability to support loads as a result of encasing. The diameter of the stone column and its modulus of encasement determine how much the axial load capacity can be increased.

In 2019, Bhatia et al. [3] tested a geosynthetic-encased column of construction detritus made of concrete filled with fly ash. Results of many model tests performed on a single column of concrete fragments from construction work installed in fly ash fill that was both unencased and geosynthetically encased. For the 25% area replacement ratio, the footing size was determined to be twice the diameter of the column. For the end bearing and floating end circumstances, 50 mm and 75 mm diameter columns have been employed. Analysis of the outcome included a look at the settlement and bearing capacity ratios. It was demonstrated by experimental model studies that the final load carrying capacity of the construction concrete debris column is considerably impacted by circumferential geosynthetic encasement, which also reduces the settlement of the treated fly ash fill bed.

Gu et al. [8] (2016) used model experiments to examine how geogrid encasement affected the lateral and vertical deformations of granular columns. Different encasement lengths for the stone column were used, as well as reinforcement systems for the geogrid-encased granular column. Measurements and analyses were made of the encasement's stress and strain properties. According to the test results, the stone columns with geogrid encasing significantly boosted the soft soil's ultimate load bearing capacity.

Geosynthetic reinforced granular columns with horizontal layers were the subject of a 2018 study by Ghazavi et al. [5]. In a laboratory, a collection of horizontally reinforced stone columns with diameters of 60, 80, and 100 mm and a single column with a diameter of 60 mm were put to the test. A numerical analysis was also done in a similar way. The experimental analysis's conclusion was that applying horizontally stacked reinforcing layers boosted the granular column's bearing capacity. According to the findings of the numerical analysis, the bearing capacity significantly rises as the number of horizontal layers and the distance between them are reduced.

By employing covered stone columns, Gupta et al. [7] (2020) evaluated the improvement of the ground. The study examines the vertically encased and horizontally reinforced stone column. Three and four unreinforced and reinforced stone columns were tested on brittle sandy soil. The study's findings indicated that reinforced stone columns may bring more weight than unreinforced stone columns. Stone columns that have been reinforced both vertically and horizontally have roughly equal bearing capacities, with a group of four stone columns that have been reinforced horizontally having a slightly higher capacity (1-2%). The acquired results were confirmed by theoretical findings.

By using granular blankets, Mehrannia et al. [11] (2017) looked into the support ability of stone columns. This study examines the ability of granular columns, granular blankets, and a combination of both techniques using reinforced and unreinforced models to support weight. With a diameter of 60 mm and a length of 350 mm, a floating style of stone column is utilized. Geotextile was used to cover the column and geogrid was used to strengthen them. A vertical geotextile encasement served as reinforcement for the granular blankets; Moreover, these blankets were left unreinforced. Biaxial geogrid was used as horizontal reinforcement to further strengthen the granular blanket. When all the results were compared, it was discovered that the effectiveness of the granular blanket and stone columns was increased by employing geogrid as reinforcement in the granular blanket and geotextile as the encasement for the stone columns. Additionally, it was discovered that combining reinforced stone columns with reinforced granular blankets allowed for the achievement of the highest carrying capacity. When the stone column was strengthened with geogrid and covered with geotextile, the stone column's bearing capacity increased.

Prasad et al. [14] (2016) looked into how a geotextile-encased column made of silica-manganese slag stone could improve marine clays. A leftover from the iron industry, silica-manganese is a slag consisting of a coarse substance. A geotextile covering with various encasement lengths surrounds the stone column. It was researched how the stone column would behave under different loads in terms of settlement and bulging. Following the observations, it was discovered that the reinforcing of the geotextile increased the capacity for carrying loads and lowered settlement.

Geosynthetically reinforced stone columns' ability to support weight was investigated by Afshar et al. [1] (2013). Stone columns that were both horizontally and vertically strengthened underwent tests in the lab. Stone columns measuring 60, 80, and 100 mm in diameter and with a length-diameter ratio of 5 were tested. Following the completion of the various tests, it was discovered that both vertical and horizontal reinforcing materials have increased bearing capacities. By boosting the strength of reinforcement in both vertically enclosed granular columns and horizontally reinforced granular columns, the bearing capacity of reinforced stone columns is also increased. Furthermore, it was determined that granular columns with horizontal reinforcement are better than stone columns with vertical enclosure.

In a series of tests, Sharma et al. [15] (2004) looked at how adding geogrid to a granular pile of soft clay would increase its load carrying ability and decrease bulging. According to the study, geogrid reinforced piles can carry more weight. The engineering behaviour improved as the number of geogrids increased and the distance between them shrank. Geogrid reinforcement has been incorporated, which has reduced the bulge's diameter and length.

In 2020, Bonab et al. [4] studied solitary stone columns that have been strengthened, with varying geotextile placements. For laboratory testing, reinforced floating stone columns with diameters of 80 and 100 mm and lengths of 400 and 500 mm were used to examine the effects of different geotextile placements. Tests on granular columns with vertical encasing, horizontal reinforcement, and a combination of both were done. According to the findings, the benefit of vertical encasement reduces as its diameter rises. However, the performance of reinforcement is increased for horizontal and vertical-horizontal encased granular columns. Comparing combined vertically and horizontally encased granular columns to other varieties, the load bearing capability also rose.

III. CONCLUSIONS

The literature review led to the following deductions. Among the effective techniques for improving the ground are stone columns. Infill materials can be effectively used as stone material. The benefit of encasing reduces as the granular column's diameter rises. Reinforcing granular columns with combined vertical and horizontal geosynthetics increased the bearing capacity and decreased settlement. The ideal geosynthetics for floating stone columns are geotextile for vertical encasing and geogrid for horizontal reinforcement. The rigidity of the small diameter stone-encased columns is increased due to the higher confining stresses in the columns. When compared to unreinforced granular columns, horizontal stone columns exhibit less lateral bulging. The tensile stiffness of geogrid is found to be greater than that of geotextiles in reinforcing stone columns. Due to low lateral confinement, stone columns built in particularly soft clays might not be able to support a substantial load. Geosynthetics can be used to surround an area, layer it internally, or do both at once to offer additional confinement.

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