Behaviour of RCA Columns Under Static Load: Experimental and Numerical Study

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Abstract:

The usage of stone columns is one of the finest methods to accentuate the terrain. Decrease soil stability while increasing soil carrying capacity. Masonry columns with full geogrid reinforcement made of recycled concrete aggregate were employed in this investigation. Soft clay soils were strengthened in a variety of methods. The results showed that using stone columns constructed of recycled concrete aggregates that were fully reinforced with geogrid resulted in a considerable improvement in soil BC. The usage of stone and double columns supported by a geogrid network enhanced the BC of the soil at the single, pentagonal, and nine columns when compared to natural soil. The improvement percentages were 7.77%, 61.1%, and 161.1%, respectively.

Keywords: (Bearing Capacity, Stone Column, Improving, Geogrid).

Introduction

The best kinds of ground reinforcement for supporting flexible structures like storage tanks and embankments are granular piles or stone columns. There is relatively little lateral constriction when building stone columns on very soft soils, which causes the columns to protrude excessively. Due to considerable bulging, the approach might not be appropriate for soft soil with an undrained shear strength of less than or equal to 15 kPa [1]. Moreover, stone columns have been widely used to support structures in soft soils by increasing bearing capacity, reducing settlements, accelerating the consolidation process, and reducing the likelihood of liquefaction [2] [4]. Despite all the aforementioned advantages, stone columns are only practicable and functional when the surrounding earth provide sufficient lateral support and confinement. So, the method of covering with ground tissues was used to enhance the functioning of the placed stone column and give superior side confinement. The stability and rigidity of the columns should be improved, as well as their capacity [5] [6]. In 1980, a test utilizing physical models was done on a large amount of earlier research that took the behaviors of models created on soft and reinforced soils with typical stone columns covered into consideration. The ability of the column to support loads was tested using granular linings. He made use of a particular kind of clay soil with a shear strength of 15 Kpa when unpolished and a water content of 26%. He employed crushed stone materials with a size range of 2–10 mm as the primary ingredient in the grout. The utilization of the geogrid blanket and the 47-degree internal friction angle both help to boost the effectiveness of the granules and the pressure concentration ratio. The outcomes showed that geogrid is more efficient than traditional blankets because it contains both vertical and horizontal drainage. Consequently, for the stone column with a diameter of 75 mm, enhanced the effectiveness of the stone column covered with a structure by 99%. The LR ratio, which was defined as LR = Lr /Lnr, where Lr is the ultimate load received from the reinforced soil, has changed. When utilizing 40 mm liner granules, the ultimate load, or Lnr, is determined from the loose soil. 1.1 to 1.28, or a 15% rise. Moreover, when utilizing a 75 mm granule liner, a 15% rise from 1.20 to 1.38 was noted [7]. In 2005, an experiment with a stone column coated in geotextile and placed on a layer of foldable soil was developed. The columns' specialty for settlements was also looked upon. The test soil was a gradually formulated combination made up of 78% concrete sand and 10% Leighton sand. Kaolin Clay, 12% With a size range of 1.18 to 2.36 mm and a shear strength of 44, gradient sand was utilized as filler. The packaging utilized is well-known in the business world. With further commissioning, the 23 mm-diameter columns were protected up to the point of collapse. A load of 100 Kpa was applied directly to the surface inside a room. It has been observed that the load on these columns increases with linear stability that reaches about 20-30% of the final load. Also, the performance has been greatly improved by increasing the strength of the stiffness of the fabric material or increasing its length.[8]. He produced unwrapped chamber columns with diameters of 60-80-100 mm and a length-to-diameter ratio of 5 for use in a different experiment. Both horizontal reinforced stone columns (HRSC) and vertical covered stone columns (VESC) were employed. This test was designed to compare the effectiveness of VESC and HRSC reinforcement types in terms of their effects on bearing capacity. In this experiment, crushed gravel with a crushed size ranging from 2 to 10 mm was employed as grouting material together with clay soils with an undrained shear strength of 30 Kpa. since the failure swell must be kept under control, L/D must be at least 4. It was discovered that utilizing VESC enhanced the soft soil's capacity. HRSC with an expansion, in order to assess and determine the sufficiency of the stone columns from the perspective of the final bearing capacity LR, where the increase of LR was noted with the presence of packaging and this is expected, and as noted the difference in the value of SCR with the increase of settlement and not constant for all columns, and note that the SCR differs in the range of 1.2 - 3.7.2.5 - 4.2.8 - 3.7 for columns with diameters of 60. [9] Because of the weak lateral pressure produced by the surroundings, stone columns in relatively loose soils are susceptible to excessive swelling. River sand was utilized as a grouting material after cutting 9 Kpa.. It was passed through a 4.75 mm sieve and has a friction angle of 30 degrees. Three types of geotextiles were used, namely nova, commercially known as mosquito net, non-woven geotextiles, and woven geotextiles. The results indicate a noticeable increase in the bearing capacity of the load due to the packaging, and the bearing capacity of the stone column depends largely on the diameter of the column itself and the hardness of the packing material. The non-woven is 250 Kpa and 410 Kpa respectively. The increase in resistance is about two to four times more than the ordinary column.

Results of laboratory tests indicated an increase in column axial stress with increasing ratios. Similar behavior is also observed for stone columns encapsulated with woven geotextile Compared to OSC, the average increase in stress for the column with l/L ratios of 0.50, 0.75and 1.00 for Column encapsulated with net are 65%, 92%, and 110% respectively and that for column encapsulated with non-woven geotextile are 90%, 139%, and 246%respectively. The load-carrying capacity of encapsulated column for the l/L ratio of 0.75 was not changed remarkably as compared to the end-bearing column (l/L = 1.00) .Stone columns encapsulated with woven geotextile exhibit much higher stress as compared to net and non-woven geotextile. The stress at 50 mm settlement of encapsulated stone column with woven geotextile with l/L ratio of 1.00 and 0.50 are 390.53 kPa and 465.98 kpa respectively, which are 1.81 times and 1.68 times the stress of stone column encapsulated with non-woven geotextile. it is observed that a stone column encapsulated with non-woven and woven geotextile over a depth equal to 4.5 times the diameter of the column has 1.91 times and 3.45 times respectively more load-carrying capacity than OSC. Also, note that the load bearing of the stone column with partial sheathing is more than 75% around the column, and the overturning column is fully wrapped and with a length equal to 75% of the length of the clay bed is close to the length of the fully wrapped end bearing column. [10]This is also what was agreed upon in[11], [12]. One of the most significant design effects, when discussing the impact of the materials used for stone columns, is how much sinking occurs and how solid the column is. Crushed stone was employed as filling for the stone column at different angles between 27 and 40 degrees during a test on soft clay soil. Take note of how the cohesion time for the reinforced clay grows as the consolidation time for each corner of the friction angles decreases. The plot demonstrated that the smallest settlement is produced by crushed stones with a friction angle of 40 degrees. He observed that when the distance between the columns increased, the stone column's leveling also increased. He also noted the highest value of the leveling at the spacing between the columns 4 m and at the angle of friction, 5.27 The degree of the stone column has a different value for the maximum value of the bulge. The maximum value of the lateral bulge was recorded for the angle of friction 27.5. The largest value was 0.0023 m, while the friction angle was recorded at 40 degrees, the lowest value was 0.0086 m. Also, it was noted that the bulge was 0.0023 m. at a friction angle of 27.5 degrees and 0.022 m at a friction angle of 28.5 degrees and 0.00125 m at 38 degrees [13] . In this field investigation, the land was improved by stone columns with a length of 1.5 meters and a diameter of 15 cm, in three different patterns, single and pentagonal, and nine columns in the case of geogrid reinforcement in a circumferential manner and compared the results with the outputs from the Plaxis 3D program.

2. MATERIALS USED:

2.1. Soil Sile

The Soft Clay used in this pilot study was classed as follows by the Universal Soil Classification System (USCS): (CL). Figure 1 displays the particle size distribution of clay. Table 1 displays the physical features of soft clay soil.

Table 1:The physical characteristics of soft clay soil

Property	Values
Type soil	Soft clay
L.L%	45
P.L%	23
Maximum dry unit weight (KN/m^3)	19.5
C (kpa)	20
Θ	4^o
E(mpa)	15
Poisons ratio	0.45
Symbol according to Unified Soil Classification System	CL

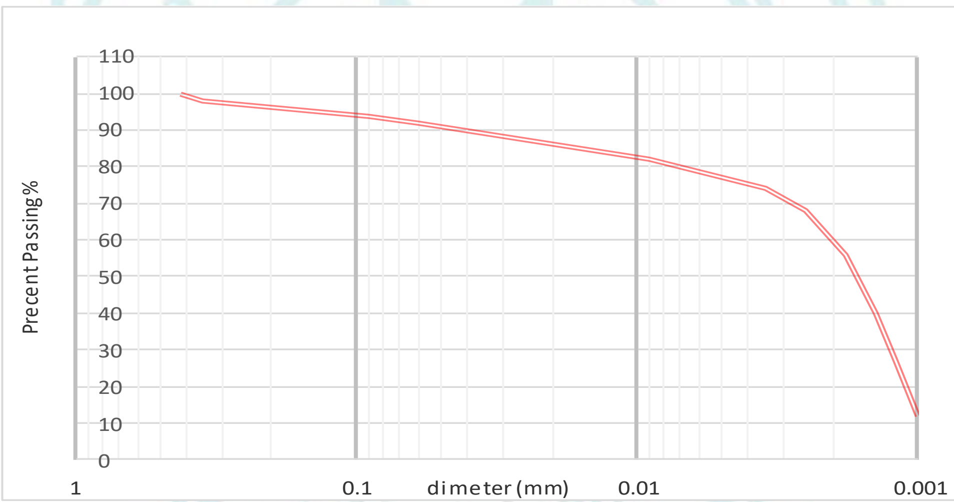

Figure 1 Grain size distribution of Soft clay

2.2-Recycled concrete aggregate

Precast concrete cubes were obtained from Dhi Qar University's consulting lab to conduct lab testing on this component. To achieve a uniform gradient, they were shattered with a hammer and put through a 25 mm filter (1-2.5 cm). Figure

2 depicts recycled concrete aggregates (RCA). The physical parameters of recycled concrete aggregates are listed in table 2 below.

Table 2:The characteristics of RCA:

Property	Values
Specific gravity	2.35
Total water absorption	2.40%
Moisture content	0.45%
Bulk density (Loose)	1355 kg/m³
Bulk density(compacted)	1590 kg/m³
Fineness modulus	6.23
Elongation Index	15.5%
Flakiness	5.8%
C(kpa)	0
Poisons ratio	0.35
Θ	45º

Figure 2:Recycled Concrete Aggregates (RCA

2.3- Geogrids

A high-density polyethylene (HDPE) net was used in the experiment. The (Netlon CE121) was made available for this publication by the Ministry of Science and

Technology. Table (3) and Figure 3 demonstrate the mechanical and physical characteristics of the Netlon CE121.

Table 3:physical characteristics of the Netlon CE121

`properties	Values
Material	High-density polyethylene
Type	CE121
Mesh aperture(mm*mm)	6*8
Weight per unit area(N/m^2)	7.15
Machine direction	9.8
Transversal direction	6.15
Machine direction	68
Transversal direction	60

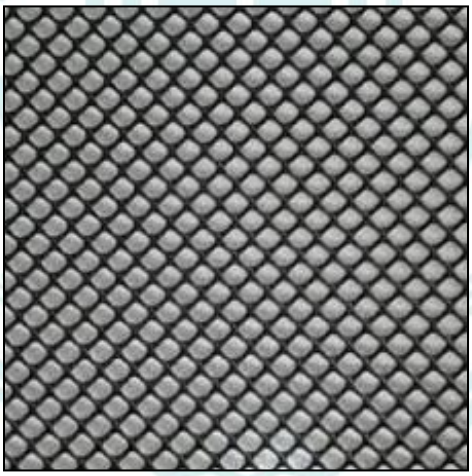

Figure 3 Netlon CE121

The steel bar was used to accurately outline and identify the place of each stone column. The stone column was drilled to a depth of 150 cm and a diameter of 15 cm using an auger machine. The auger machine's blades were inserted into the stone column. Geogrid reinforcement was also cut into circular layers with an 8-9 cm diameter to be put into the column. The strain gauge was subsequently mounted on the reinforcement column's circler layers and owner surface. The geogrid reinforcement has been placed chorally. Inside the enclosed hollos, six layers of recycled concrete aggregates (RCA) were poured. The RCA material was condensed using a vibrating machine. After that, the strain gauge was linked to and installed on the geogrid column. The ground surface was covered with nylon and using a vibrating machine strain gauge, recycled concrete aggregates (RCA) were introduced into the geotextile cavity. Figure 4 shows the sample preparation process

Figure 4:the sample preparation process

.4- SET THE RECYCLED CONCRETE AGGREGATES (RCA) COLUMN AS NEEDED

Case 1.

In this model, soft clay soil was obtained in its natural state with no modifications, and a numerical investigation was performed on it in addition to an assessment of precipitation and load-bearing capacity in its natural state.

Case 2

In this case, the effect of reinforcement was investigated using Recycled Unwrapped Concrete Aggregates (RCA). Figure 5 shows the patterns for this case were

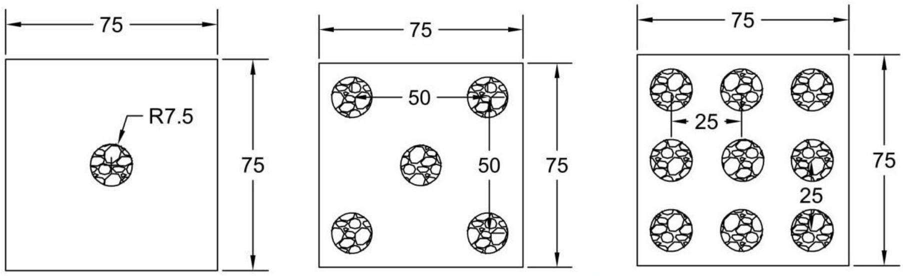

Figure 5: the patterns for this case were

Case 3

The impact of reinforcing was explored in this example utilizing Recycled Concrete Aggregates (RCA) Figure 6 depicts the patterns of this example where geogrid casing with diameter and length of 15 cm and 150 cm was utilized to cover the Recycled Concrete Aggregate (RCA) patterns

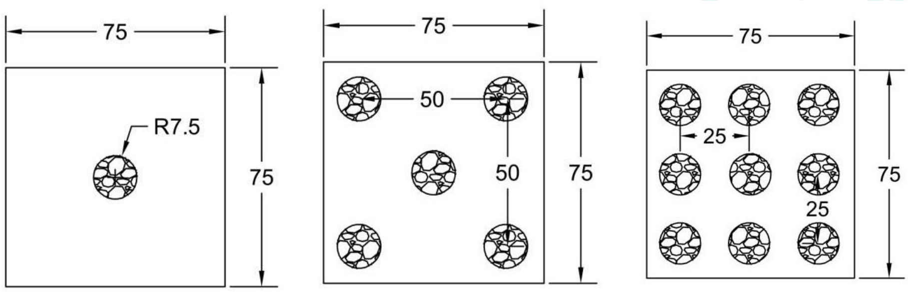

Figure 6: the patterns for this case were

5. TEST PROCEDURES

The piles were strengthened with 12-millimeter rebar, five bars for each pile. It was vertically welded using an oxygen torch until it reached 43.5 cm in height. Following that, an antioxidant was used to stain it. Following the welding of a steel foundation with a thickness of 12 mm into the concrete pillars, the complete steel structure was erected on the pillars while the horizontality and straightness were regulated. He set up two LVDT landing sensors on either side of a test plate supported by a side stand. All sensors, sensors, and measuring devices were connected to data recorders after the plate load test. A geotechnical data collecting system was used to measure and record the outputs of load cells, displacement transducers, and strain gauges. To track the progress of trials, data is automatically uploaded to a computer in real-time. Transducers for pressure, linear LDT transducers, LVDT tuning transducers, strain gauge load cells, and potentiometric displacement are all compatible. A steel foundation measuring 75*75 cm and 25 mm thick was employed, and soil was dumped in up to 64 different channels at a depth of 10 cm beneath the area's base. Figure 7 displays the examination process's field methods.

Figure 7: The process of checking and connecting devices

6. Result of Field

6.1- Soil test normal (soft clay)

Figure 8 The double tangent technique was used to obtain the ultimate carrying capacity value, which reveals the relationship between pressure and settling of untreated soft clay soil with stone columns. The BC value was determined to be about 90 kpa, leading to a settlement of 29.5 mm.

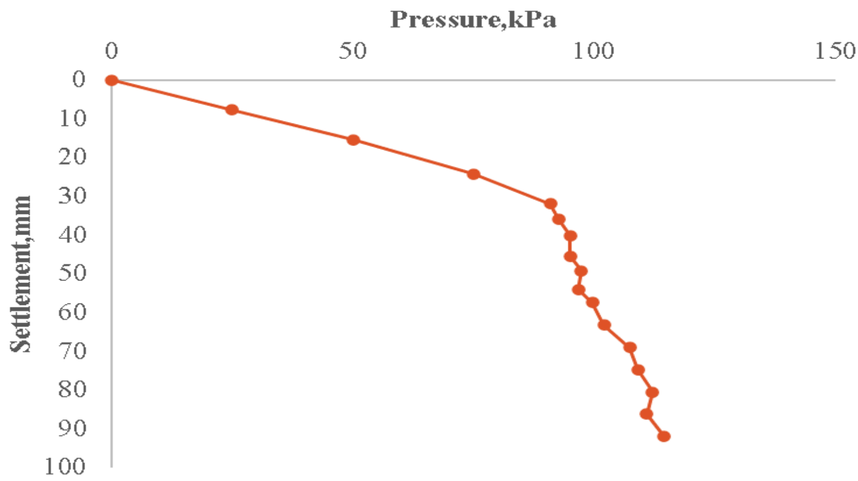

Figure 8. Therelationship between pressure and settlement for untreated soft clay soils

A stone column covered with geogrids packed with recycled concrete aggregates (RCA) was placed in this project to evaluate the influence of the reinforced column on soft clay soil behavior. (Figure 9) depicts the relationship between applied pressure and settlement of the reinforced stone columns. We notice an increase in the soil's absorptive capacity, which was improved by one stone column covered with a layer of geogrid, where the absorptive capacity reached 97 kPa compared to untreated soil, which amounted to 90 kPa. because the packaging offers enough lateral constriction to withstand the applied stresses, as well as the casing, has a significant effect in raising the stiffness that develops. Once the improvement rate hit 1.15, the carrying capacity increased while the leveling decreased. In comparison to natural soil, the improvement rate was 7.77%.

To enhance the qualities of the weak and soft clay soil, five stone columns were put in this study. The graph shows a noticeable rise in ultimate load capacity as well as a decrease in leveling rate, in addition to the influence of the number of columns embedded under the foundation on bearing capacity. The packing has an obvious impact since the clay and its hardening do not offer enough restricting pressure. as the packing overcame this shortcoming as well. The encapsulation increases the tensile strength of the stone columns. Furthermore, the initial strain of the geogrid that occurs during fixation also contributes to improving the rigidity of the stone column and the reduction of settlement when compared to the total absorptive capacity of the untreated soil, which reached 90 kpa. The improvement in the coated columns was 145 kpa, or double the value, equating to a 29.9 mm improvement in the leveling rate. The improvement rate was calculated using the relationship and came to 1.88. In comparison to natural soil, the improvement rate was 61.1%.

This is also evident from the schematic layout of the stone pillars arranged in a 3 * 3 grid. Figure 9 depicts the pressure applied between the untreated soil and the soil supported by a grid of 3 * 3 stone pillars covered with a geogrid. The carrying capacity increased by 235 kPa, resulting in a 15.5 mm decrease in a settlement. and a 2.88 percent rise in the pace of progress. The coating is necessary because it eliminates lateral swelling and offers excellent containment to the stone columns. As the package's maximum tensile capacity grows, so does its maximum carrying capacity. In comparison to natural soil, the improvement rate was 161.1%.

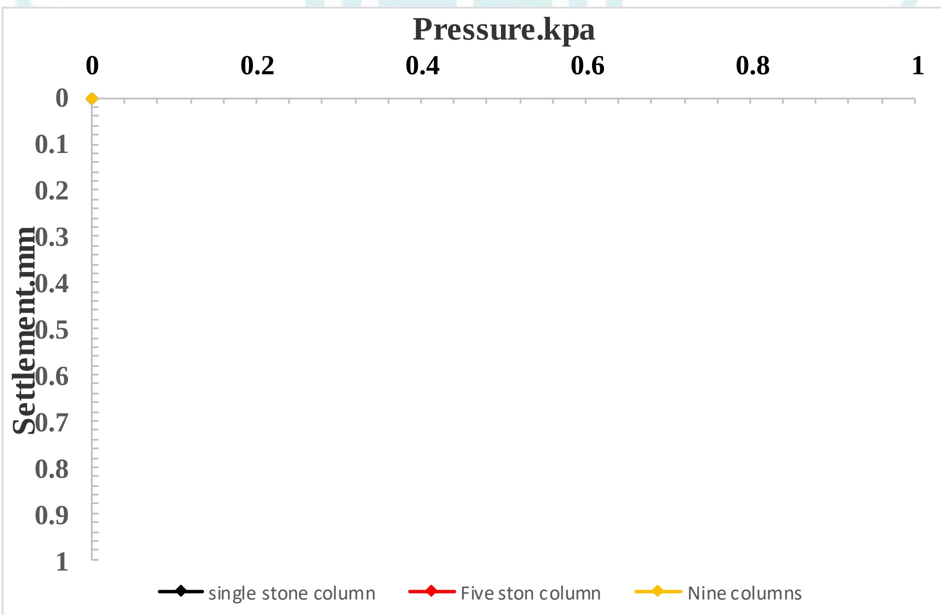

Figure 9. Relationship between applied stress and stability of masonry columns of recycled concrete aggregates reinforced with geo-cladding materials (RCA).

7. Result of Field

7.2-Reinforced Recycled Concrete Aggregates (RCA) Columns of Plaxis 3D

From Figure 10, the relationship between applied pressure and settlement for the same patterns mentioned previously, we notice a remarkable convergence in terms of results, as the bearing capacity of a single stone column reached 96kPa, for five stone columns 150kPa, and finally nine columns 255kPa. With an improvement rate of 6.66%, 66.6% and 183.3%, respectively.

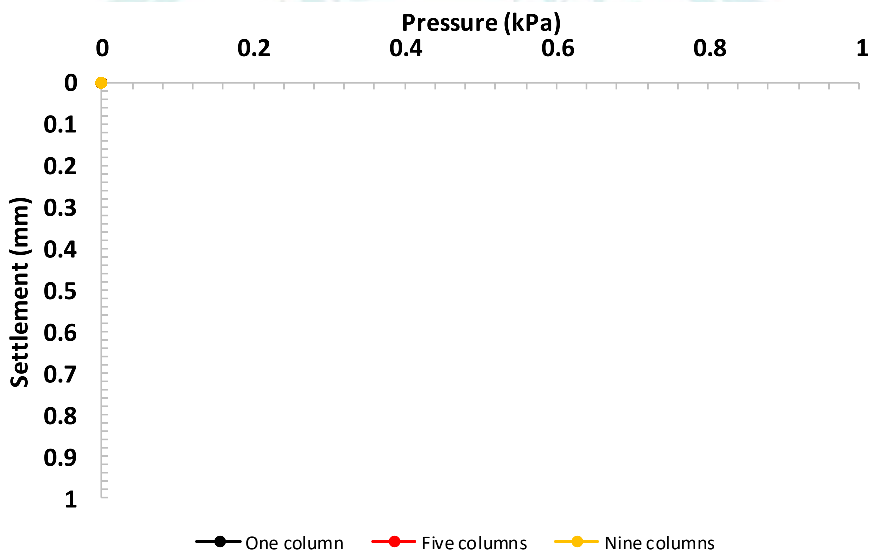

Figure 10. The relationship between applied pressure and settlement of the analyzed stone columns Plexis 3D program

8. CONCLUSIONS

1. It is inexpensive to use recycled concrete aggregates (RCA).

2- Stone columns made of recycled concrete aggregates (RCA) efficiently enhanced poor soils.

3- Unlike traditional stone columns, geosynthetic-encased stone columns usually exhibit linear behavior in response to pressure settlement without catastrophic fracture. The stiffness of the geosynthetic material used for encasing influences how much the load capacity is improved by the geosynthetic encasement.

4- The stiffness of the geosynthetic used for the encasement also impacts the performance of the stone column.

5- Encasing the granular blanket reinforcement in geotextile and geogrid as the stone column boosts its efficacy. Increases the stiffness of the reinforced soil and stone column. When the soil particles become trapped in the stiff, tensile geogrid apertures, significant frictional forces are created at the geogrid-soil contact. Moreover, geotextile boosts bearing capacity by preventing the components of the stone column from sinking into loose soil.

9.Acknowledgment

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