# IMPROVING WEAK SOILS WITH REINFORCED STONE COLUMNS

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# ABSTRACT

*The usage of stone columns is one of the best ways to accentuate the ground. minimize settlement and increase the soil's carrying capacity. In this study, stone columns with complete geogrid reinforcement built of recycled concrete aggregates were utilized. Soft clay soils have been strengthened in a variety of methods. The results indicated that the use of stone columns made of recycled concrete aggregates fully reinforced with geogrid resulted in a significant improvement in the BC of soils. Compared to natural soil, the use of stone and double columns reinforced with a geogrid network improved the BC of the soil by 9% with an increase in the percentage of improvement when using other patterns.*



# KEYWORDS

*Bearing Capacity, Stone Column, Improving, Geogrid*


# INDEX




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# 1. INTRODUCTION

Soft clayey soils are widespread across the world, and they may be found in Iraq's central and southern regions, notably in areas close to wetlands. Since cities are quickly growing and the population is rising, one of the key answers is to improve the geotechnical properties of soft soils since it is essential to use such soil as a foundation or construction material for various projects. There are several techniques for enhancing soft soil. To fortify the brittle clay soil, stone columns are used. It has an undrained shear strength (cu) of 10 Kap and is exposed to various types of stresses Stone columns can be used to increase the shear strength of soft soil, speed soil consolidation, and reduce the possibility for soil liquefaction. The stone columns are referred to as floating stone columns because, when a thick, soft layer is deeper than 25 meters, they do not reach the stable layer of soil. (Datye, 1982; Abdullah et al., 2020) (1,2). (2017) (Fattah et al.) Length to the diameter of the stone column The strength of stone columns was allegedly affected by several factors, including the column's stiffness, length, diameter, and replacement ratio for the area, according to several past studies (3). (2012) Mohammed Al-Wailey A laboratory study was presented to examine the relationship between the load improvement and the percentage of the replaced area by using different diameters (20-30-40-50-60 mm), which corresponds to the area replacement ratio. This study was done regarding the effect of the area replacement ratio on the load-bearing capacity of the soil treated with stone columns (0.042). - 0.099 - 0.333 - 0.563 (within a test container used in laboratories with varied shear strengths) (inside a test container used in laboratories with various shear strengths) 11, 16, and 22 kpa. The results show that the tolerance improvement ratios are 1.16, 1.29, and 1.64. 2.29, Along with the growth of stopping additional loads when the final settlement reached 40 mm in soils with a shear strength of 11 Kpa and treated with stone columns at a replacement ratio of 0.042 - 0.099 - 0.333 - 0.563) respectively, it was also noticed that the percentage of increased Slightly bearing with increasing load and reaching the top by the end of the test and also found the highest percentage of improvement of soil resistance at shear strength 16 Kpa (4). Numerous researchers have expressed similar opinions (5–11). A lab experiment was conducted to show how the stress concentration ratio is impacted by various circumstances (SCR). The peak stress concentration ratio when the internal friction angle of the stone column was between 4 and 5.5 was noted to be between 4-6 for a group of parameters and materials. This differs from 38 the 42 and is also significantly influenced by the thickness of the blanket material forming the column and the strength of the surrounding soil (12). In theory, both are consistent with this (Barksdale and Bachus, 1983, Han and Ye 1991, Aslani and J. Nazariafshar 2021) (13–15). Some research and studies have turned to encase the stone column in geogrid or another high-tension material to counteract the weakness caused by a flaw in the soil around it. Where it was noted that the packing boosts the stone column's bearing capacity and hardness and that the coated stone column behaves significantly better than the unwrapped column (16,17). Researchers found that encapsulating the upper portion of a stone column at 2.5 D (D) the pillar's diameter has demonstrated its usefulness in this field, resulting in a precipitation reduction of up


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to 50%. (18,19). The encasement, which has several advantages, further restrains the stone column. increased column stiffness, prevention of stone loss into the soft clay around it, and preservation of the drainage and frictional properties of the stone aggregates (20–22). The bearing capacity and porosity pressure are influenced by the distribution of various types of stone columns. This was proven through a laboratory experiment in which soil with a very low shear resistance of 5.5 Kap was obtained, and several patterns (single, bi-plan, triangle, quadrilateral, and square) were taken. The stone has a 180 mm diameter and a 30 mm diameter when it reaches the length of the column. The material of the stone column has a friction angle of 48.5 degrees. He noted that despite the percentage of replacement in the area is very small, he noticed an increase in the loading capacity of 79, 97, 132, 148, and 145%, respectively. He also noted that the use of the square pattern is more effective. of the square distribution even though they have the same area substitution ratio (22). In this study, the stone columns covered with a comprehensive cover with a length of 1.5 meters and a diameter of 15 cm were discussed. The examination was conducted in a field manner, and several patterns were taken (double, quadruple, pentagonal, column).

# 2. MATERIALS USED:

## 2.1. SOIL SILE

The Uniform Soil Classification System (USCS) assigned the Soft Clay used in this pilot study the following classification: (CL). The clay particle size distribution is seen in Figure 1. Table 1 illustrates the physical characteristics 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 | 4º |
| E(mpa) | 15 |
| Poisons ratio | 0.45 |
| Symbol according to Unified Soil Classification System | CL |


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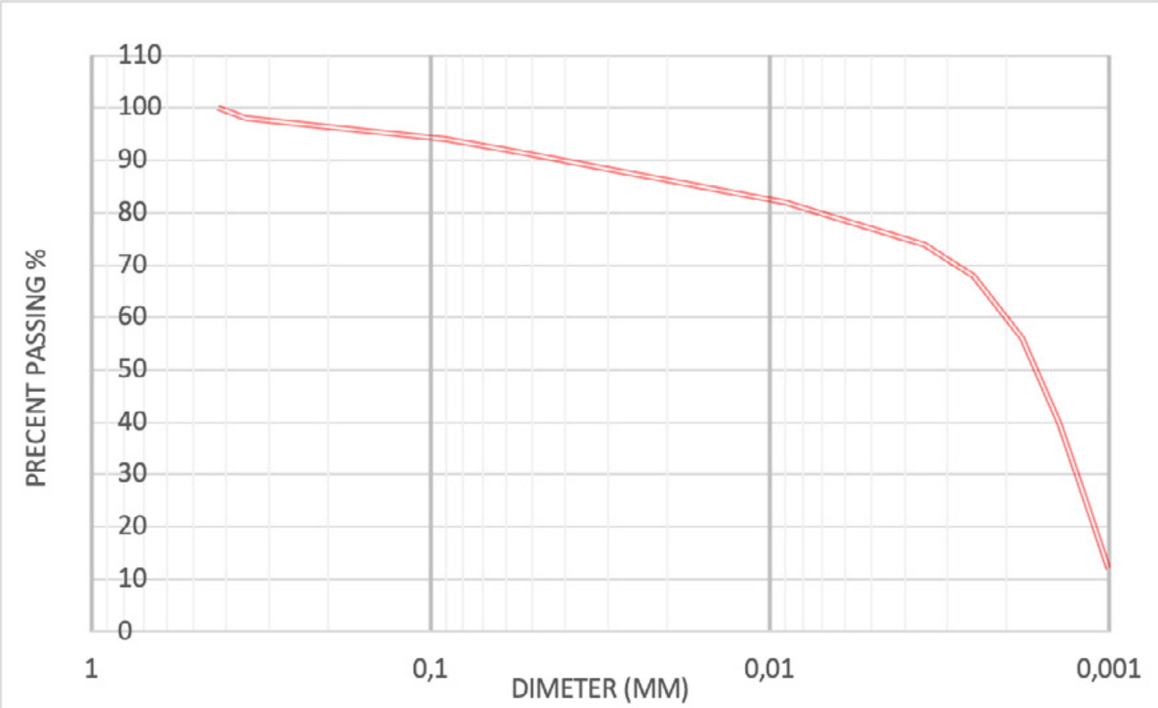


**Figure 1.** Grain size distribution of Soft clay

## 2.2. RECYCLED CONCRETE AGGREGATE

**Precast** concrete cubes were obtained from the consulting lab of Dhi Qar University to carry out the lab testing for this component. To achieve a steady gradient, they were broken up with a hammer and sent through a 25 mm filter (1-2.5 cm). aggregates from recycled concrete, Figure 2. (RCA). The physical attributes of recycled concrete aggregates are listed in Table (2). (RCA).

**Table 2.**The characteristics of RCA:

| Property | Values |
|---|---|
| Specific gravity | 2.35 |
| Total water absorption | 2.40% |
| Moisture content | 0.45% |
| Bulk density (Loose) | 1,355 kg/m$^3$ |
| Bulk density (compacted) | 1,590 kg/m$^3$ |
| Fineness modulus | 6.23 |
| Elongation index | 15.5% |
| Flajiness | 5.8% |
| C (kpa) | 0 |
| Poisons ratio | 0.35 |
| Θ | 45° |


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**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 show the mechanical and physical properties 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/m²) | 7.15 |
| Machine direction | 9.8 |
| Transversal direction | 6.15 |
| Machine direction | 68 |
| Transversal direction | 60 |


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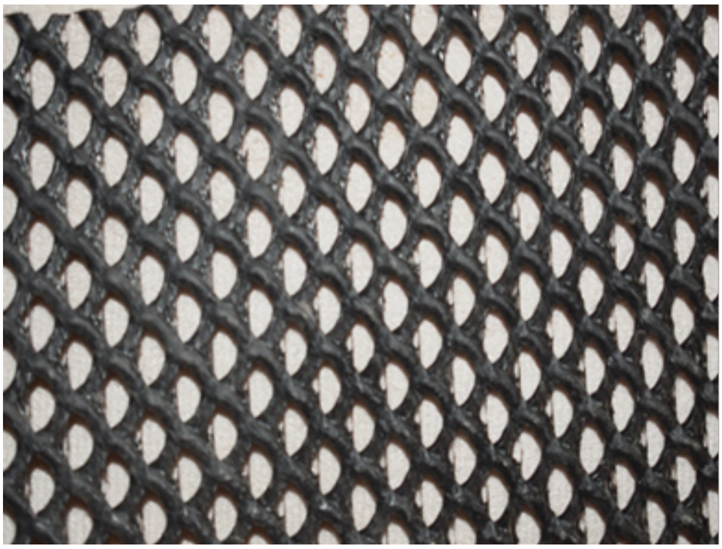

**Figure 3.** Netlon CE121

# 3. SETUP OF THE STONE COLUMN

The position of each stone column was precisely delineated and indicated with the steel bar. An auger machine was used to drill the stone column to a depth of 150 cm and a diameter of 15 cm. The auger machine sent its blades into the stone column. To be inserted into the column, geogrid reinforcement was also cut into circular layers with an 8–9 cm diameter. The circler layers and owner surface of the reinforcement column were then installed with the strain gauge. The geogrid strengthened down has been installed chorally Six layers of recycled concrete aggregates (RCA) were poured within the enclosed hollos, and the RCA material was compacted using a vibrating machine. Following that, the strain gauge was attached to and installed on the geogrid column. The ground surface was covered with nylon, and a vibrating machine strain gauge was used to insert recycled concrete aggregates (RCA) into the geotextile cavity.

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

**Case 1.**

In this model, soft clay soil was taken in its natural form without any improvement, and a numerical examination was conducted on it in addition to the examination of precipitation and the amount of load bearing in its natural form

**Case 2.**

In this case, the effect of reinforcement was investigated using Recycled Concrete Aggregates (RCA) Figure 4 shows the patterns of this case where geogrid casing with


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diameter and length of 15 cm and 150 cm was used to cover the Recycled Concrete Aggregate (RCA) patterns.

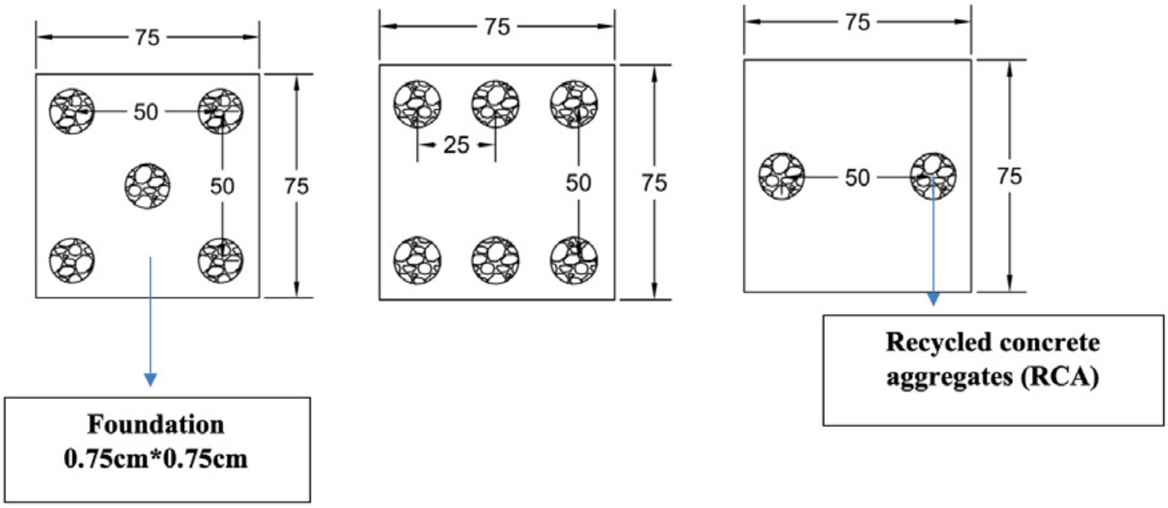


**Figure 4.** Patterns of stone columns with layers of geogrid with comprehensive encapsulation

## 5. TEST PROCEDURES

Twelve-millimeter rebar was used to strengthen the piles, and five bars were added to each pile. With the use of an oxygen torch, it was vertically welded until it reached a height of 43.5 cm. After that, an antioxidant was used to stain it. The complete steel structure was put on the pillars while regulating the horizontality and straightness after a steel foundation with a thickness of 12 mm was welded into the concrete pillars. He placed two of his LVDT landing sensors on either side of a test plate that was supported by a side stand. All sensors, sensors, and measurement tools were attached to data recorders after the tests were conducted using a plate load test. Using a geotechnical data collecting system, the outputs from load cells, displacement transducers, and strain gauges were measured and recorded. To monitor the status of trials in real-time, data is automatically uploaded in real-time to a PC. Compatible with pressure transducers, linear LDT transducers, LVDT tuning transducers, strain gauge load cells, and potentiometric displacement transducers. A steel foundation with dimensions of 75*75 cm and a thickness of 25 mm was employed, and dirt was deposited in a layer of 10 cm under the base of the area in up to 64 distinct channels. The field methods for the examination process are shown in Figure 4.


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**Figure 5.** The process of checking and connecting devices

# 6. RESULTS

## 6.1. SOIL TEST NORMAL (SOFT CLAY)

Figure (6). The ultimate carrying capacity value, which shows the connection between pressure and settling of untreated soft clay soil with stone columns, was calculated using the double tangent approach. The BC value was discovered to be around 90 kpa, translating to a settlement of 29.5 mm.

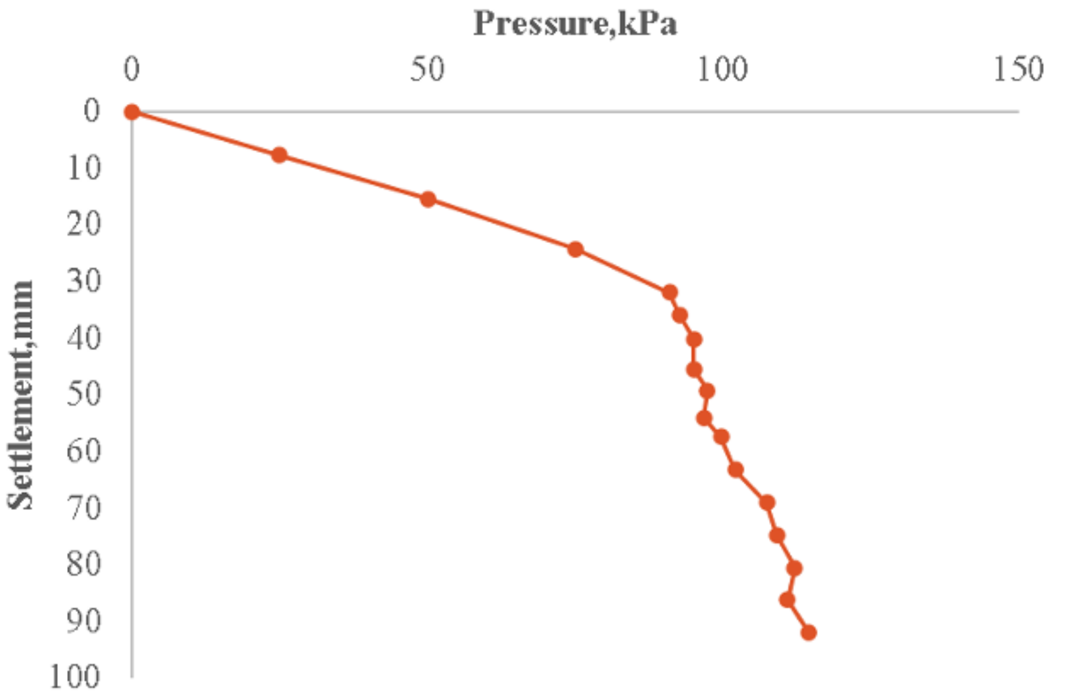


**Figure 6.** Therelationship between pressure and settlement for untreated soft clay soils


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## 6.2. REINFORCED RECYCLED CONCRETE AGGREGATES (RCA) COLUMNS

In this investigation, seven different types of stone columns consisting of recycled concrete aggregate (RCA) reinforced in annular form with geogrid were installed.

In this test, two stone columns were installed which were wrapped by geotextile nets to improve the bearing capacity of soft clay soil. From the results, we notice a clear increase in the final load-bearing capacity of the soil treated with two stone columns coated with geogrid, where the final carrying capacity reached 110 kpa, offset by a decrease in leveling of 29 mm. The encapsulation increases the radial pressure at all stages of loading. In addition, it provides an increase in lateral excavation, and from the previously mentioned relationship, the improvement ratio is about 1.29. in this research, five stone columns were installed inside the weak and soft clay soil to improve its properties. We notice from the graph a clear increase in the final load capacity, as well as a clear decrease in the leveling rate, in addition to the effect of the number of columns embedded under the foundation in increasing the bearing capacity. There is a clear effect of the packing, as the clay and its hardening do not provide sufficient confining pressure, as the packing overcame this deficiency as well. the encapsulation increases the tensile strength of the stone columns, in addition to that, not the limitation and hardness was the reason for that improvement, but 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 85 kpa. The improvement in the coated columns amounted to 160 kpa, i.e., double the value, corresponding to an improvement in the leveling rate, which reached 29.9 mm. From the relationship to find the improvement rate, it amounted to 1.88.

In this field research, several stone columns were installed inside the weak and soft clay soil. We notice a very clear improvement in the carrying capacity of the applied loads when compared to the untreated soil. The reason is due to the strengthening of the vertical position and the drainage layer of the stone column by acting as a good filter file to prevent the mixing of fines with the stone material produced by the packaging, as it resists the tensile strength of a collar in the casing and develops confining pressure to prevent the occurrence of Lateral bulging as well, whenever the pressure in the casing increases, the stiffness of the stone column increases, and thus this increases the final absorption capacity and a clear decrease in leveling, as the absorption capacity after improvement reached 190 kpa, corresponding to a decrease in leveling at a rate of 25 mm. The improvement ratio was found to be 2.2. Figure 7 shows the relationship between applied pressure and settlement for the selected stone columns


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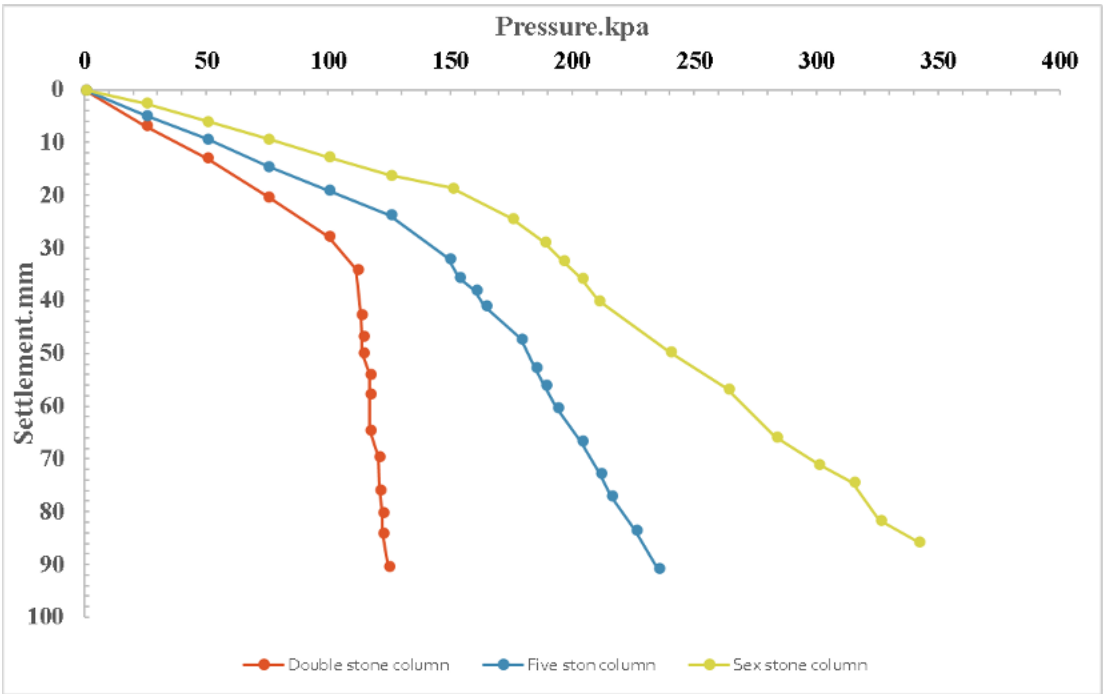


**Figure 7.** Relationship between applied stress and stability of masonry columns of recycled concrete aggregates reinforced with geo-cladding materials (RCA).

The percentage improvement achieved by the stone columns is represented by the relationship. Table 4. shows the endurance capacity ratio (BCR) values.

$$BCR = \frac{\text{bearing capacity of reinforced soil}}{\text{bearing capacity of unreinforced soil}} \quad (1)$$

**Table 4.** The bearing capacity ratio (BCR) values

| Number of stone columns | Bearing capacity ration BCR% |
|---|---|
| 2 | 1.69 |
| 5 | 1.88 |
| 6 | 2.2 |

# 7. CONCLUSIONS

1. It is affordable to employ recycled concrete aggregates (RCA).
2. Using stone columns composed of recycled concrete aggregates (RCA) improved weak soils effectively.
3. In contrast to conventional stone columns, geosynthetic-encased stone columns frequently display linear behavior in response to pressure settlement without displaying any catastrophic breakage. The stiffness of the geosynthetic

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material used for encasing determines how much the geosynthetic encasement improves the load capacity.

4. The rigidity of the geosynthetic utilized for the encasement also affects how well the stone column performs.

5. Using geotextile and geogrid as the stone column, encasing the granular blanket reinforcement increases its efficacy. increases the reinforced soil and stone column's rigidity. Due to the soil particles being caught in the stiff, tensile geogrid apertures, considerable frictional strengths are generated at the geogrid-soil interface. Additionally, geotextile increases bearing capacity by preventing the stone column's components from sinking into loose soil.

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