Experimental and Numerical Investigation of Bearing Capacity of Encased Stone Column

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Abstract

One of the finest methods to highlight the area is to utilize stone columns. 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. When compared to natural soil, the usage of stone and double columns reinforced with a geogrid network increased the bearing capacity of the reinforced stone columns by 16.6% for two columns and 23.3% for four columns

1.Introduction

The most popular column-type method for enhancing soft soils is the use of stone columns with sand compaction piles. Compared to soft soil, they have great stiffness and compressive strength. They not only provide reinforcement and drainage, but they also boost the ground's carrying capacity and lessen soft ground's tendency to settle. Depending on the installation method, the earth surrounding the column is compressed because of the dirt being moved about during installation, improving the soil's stiffness. The vibro-compaction method, the vibro-composer method, the overreplacement method, and other installation techniques are all employed globally. and ramming by dropping a hammer (15 to 20 kN). The effectiveness of the load redistribution to the columns mainly depends on the lateral support from the surrounding soft soil. The lateral support is expressed using the undrained shear strength. According to German regulations, the application of stone columns is generally limited to soils with undrained shear strength cu = 15 - 25 kN/m Stone columns are also occasionally used in very soft soils with an undrained shear strength cu < 10 kN/m² (Raju 1997). Generally, however, there is a risk in installing stone columns in sensitive or organic soils [1].

Stone columns, also known as granular piles or granular columns, offer an affordable means of support in compressible and fine-grained soils for low-rise buildings and structures like liquid storage tanks, abutments, embankments, and factories that can tolerate some movement. Stone columns are either built to fully penetrate a layer of clayey soil that sits on top of a hard stratum, or they are built to float (or partially penetrate), with the ends of the columns embedded in the clayey soil layer [2].performed seven field tests in Baghdad city to investigate the bearing improvement ratio and the settlement reduction ratio in the case of the ordinary stone column and when reinforcement of steel discs is used in the upper part of the column. The tests were carried out with an area ratio of (0.042) to (0.18). The findings demonstrated that adding reinforcement to the top half improved bearing ratios by 0.16 and 1.78 for two and three reinforcement discs, respectively, with corresponding settlement reduction ratios of 0.25 and 0.22 [3]. based on a two-dimensional finite element approach, a numerical model was created. For a given set of columns, soil, and loading conditions, the model can distinguish between the many ways that single and multiple stone columns might fail. In these situations, group interactions were looked at and assessed. A parametric study was conducted on the parameters believed to govern this behavior. The results produced in this study showed that ground reinforced by a group of stone columns may fail by general, local, or punching shear failure, depending on the geometry of the group and the properties of the surrounding soils [4].

several numerical calculations were carried out to assess the bearing capacity and settling of a strip footing lying on soil reinforced by a number of stone columns. The bearing improvement ratio, or (BCR) values, is discovered to be mostly dependent on footing width. With an increase in footing width, the BCR might drop in some replacement ratios. The influence of footing width on BCR decreased as replacement ratio increased [5].A statistical equation had been proposed to estimate the ultimate bearing capacity of soft soil treated with floating stone columns using the Statistical Package for the Social Sciences

(SPSS) program. The data used in this analysis were obtained from experimental work and collected from previous studies. The proposed equation is applicable for clays that have undrained shear strengths in the range (4–25) kPa and with several aspect ratios of length to the diameter of the stone column [6]. Numerous earlier studies claimed that a variety of elements, including the ratio of the column's area replacement to its length, diameter, and stiffness in comparison to the soil around it, the concentration of stress between the columns, and the installation process, all have an impact on stone columns. Additionally, the improvement of soft soil using stone columns depends primarily on the end bearing of the stone columns and confinement stress applied to the surrounded soil under the static loads, but there is a limited amount of knowledge about the behavior of floating columns in thick layers of soft soils [7His geotextile casing has been effectively employed in recent years to expand the usage of stone pillars to extremely soft soil. In addition to providing lateral support, geotextiles in the casing serve as a filter between clay and sand, ensuring efficient drainage and preventing fines-related sand pollution. Other artificial floor materials, as geogrid Column coverings [8]– [9], are now also in use. In this study, the stone columns covered with a comprehensive covering were discussed with a length of 1.5 m and a diameter of 10 cm. The examination was conducted in a field manner, and several patterns were taken (Two stone column, four columns,). In the case of reinforcement and non-reinforcement.

2.Materials

2.1. Soil

The Soft Clay utilized in this pilot research was categorized by the Uniform Soil Classification System (USCS) as (CL). Figure 1 depicts the distribution of clay particle sizes. The physical characteristics of soft clay soil are shown in Table 1

Table 1:Physical properties of the treated soil

Property	Values
Type soil	Soft clay
L.L%	45
P.L%	23
Maximum dry unit weight (KN/m³)	19.5
C (kpa)	20
Θ	4º
E(mpa)	15
Poisons ratio	0.45
Symbol according to Unified Soil Classification System	CL

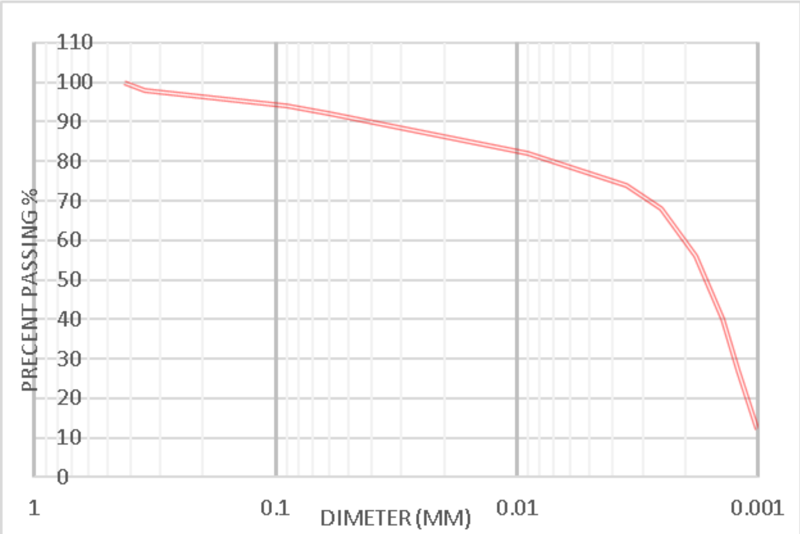

Figure 1:the distribution of clay particle sizes

2.2. Recycled concrete aggregate

Precast concrete cubes were obtained from Dhi Qar University's consulting laboratory for use in this section's laboratory testing. To guarantee a consistent gradient, they were broken up with a hammer and put through a 25 mm sieve (1−2.5 cm (See Figure 2 for recycled concrete aggregates (RCA). The physical characteristics of recycled concrete aggregates are presented in Table (2). (RCA). Table2: The characteristics of Recycled concrete aggregate

TABLE 2: **The physical characteristics of recycled concrete aggregates are presented**

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. Geogrid

In the experiment, a high-density polyethylene (HDPE) net was employed. The Ministry of Science and Technology made the (Netlon CE121) accessible for this publication. The mechanical and physical features of the Netlon CE121 are shown in Table (3) and Figure 3.

Table3.. The physical and mechanical properties of the Netlon CE121

Property	Value
Unit weight(kg/m²)	0.74
Aperture size (mm)	6 × 8
Rib thickness(mm)	1.6/1.4
Rib width(mm)	2/2.75
Junction thickness(mm)	2.75

Roll width(m)	4
Roll length(m)	50
Peak Tensile Strength (KN/m)	6.4
Elastic modulus (GPa)	0.39
Tensile strength (Mpa)	9
Total extension Strength (Mpa)	5
Total elongation%	11

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. Figure 4 illustrates the sample preparation process.

Figure 4 illustrates 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

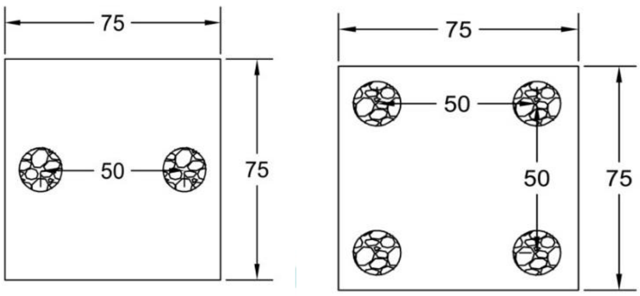

Figure 5:the patterns for this case were

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.

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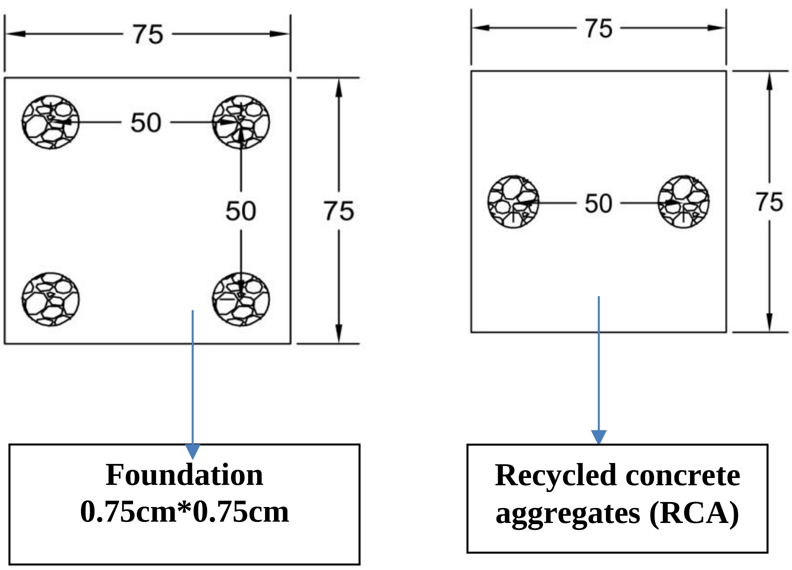


Figure 6 Patterns of stone columns with layers of geogrid with comprehensive encapsulation

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 7

Figure 7: The process of checking and connecting devices

6 RESULTS of Field

6.1- Soil test normal (soft clay)

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

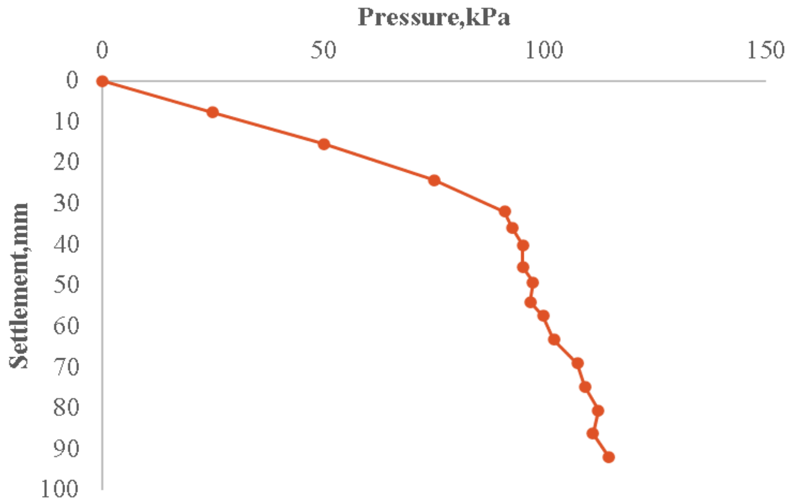


Figure 8 Therelationship between pressure and settlement for untreated soft clay soils

6.2-Reinforced Recycled Concrete Aggregates (RCA) Columns

Seven distinct types of stone columns made of recycled concrete aggregate (RCA) reinforced in annular form without geogrid were placed in this study.

Figure 9 shows two stone columns that were placed to increase the bearing capacity of soft clay soil. The graph shows a noticeable improvement in loading capacity with the increase in the number of stone columns to two columns, as the bearing capacity reached 105 kPa, corresponding to a 30 mm settlement. It was calculated using the double shadow method, and when compared to the untreated soil, we notice a good improvement in the pressure-bearing capacity, as well as an increase in the proportion of stress concentration on the stone columns, and this increases with the time of consolidation, and from the previously indicated relationship, the percentage of improvement in the soil was extracted, which amounted to 1.188. There are two stone columns for soil treatment. In comparison to natural soil, the improvement rate was 16.6%.

Stone columns were erected in this pattern in the form of a 2 * 2 grid in a square shape, with center-to-center diameters of 50 cm. The pressure-bearing was estimated using the double tangent technique, and the highest bearing value reached 111 kpa, equating to a settlement of 37 mm and a notable rise for untreated soil. This is attributable to an increase in the number of columns beneath the square foundation, as well as an increase in the stress distribution area on the columns and a reduction in the load on the weak soil, with a percentage of improvement of 1.37 discovered. When compared to natural soil, we see that the improvement rate is faster.

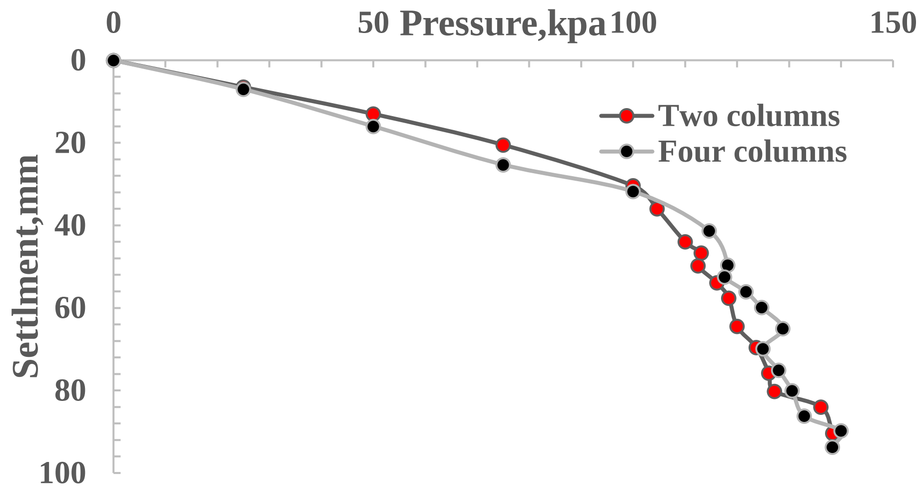


Figure 9 Relationship between applied stress and stability of masonry columns of recycled concrete aggregates reinforced without geo-cladding materials (RCA).

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

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

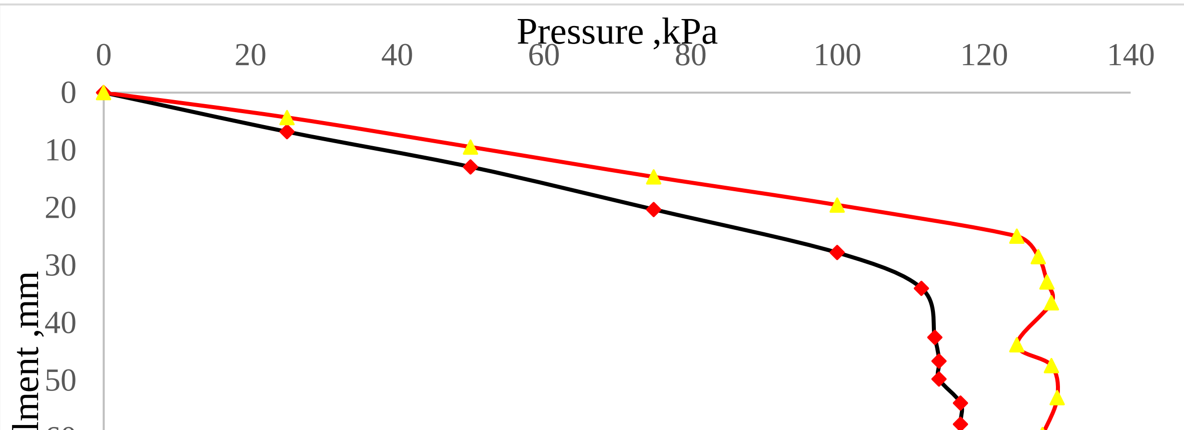
Table 2 The bearing capacity ratio (BCR) values

Number of stone columns	Bearing capacity ration BCR %
2	1.29
4	1.37

6.2– Rreinforced Recycled Concrete Aggregates (RCA) Columns

Figure 10 shows two stone columns coated in geotextile nets that were put in this test to increase the bearing capacity of soft clay soil. The results show a substantial improvement in the ultimate load-bearing capacity of the soil treated with two stone columns coated with geogrid, reaching 111 kpa, offset by a 29 mm decrease in leveling. At all phases of loading, the encapsulation raises the radial pressure. Moreover, it increases lateral excavation, and the improvement ratio is around 1.29 based on the previously indicated connection. In comparison to natural soil, the improvement rate was 23.3%.

Laminated stone columns are erected in the shape of a 2*2 square grid with 50cm center-to-center measurements in this design. The results show that the casing helps to facilitate load transmission to the depths of the deep earth. The casing also helps to keep the stones that make up the column clean, which leads to improved long-term performance of the stone pillar since the frictional characteristics of the recycled aggregate stay unaltered. Moreover, the casing shrinks greatly due to the confinement given by the geogrid cover; as a result, increasing the performance of the stone column by lowering stability and preventing failure in the stone column. All of these factors contributed to an increase in the absorptive capacity of the soil enhanced by the coated stone columns, which reached 125 kpa, equating to a reduction in settlement of 27.5 mm, indicating a noteworthy improvement. Furthermore, when compared to untreated soil, the improvement rate was determined to be 1.47. In comparison to natural soil, the improvement rate was 38.8%.



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7.Results of Plaxis 3D

7.1- Soil test normal (soft clay).

The initial bearing capacity of the soil reported in numerous unimproved soils was evaluated using a solid base lying on the soil to be studied. The load leveling relationship is a straightforward way to calculate the final bearing capacity. The load-settlement relationship curve (Figure 11) was evaluated using PLAXIS 3D. The maximum bearing capacity of unimproved soil was determined using the leveling curves of the double tangent technique to be (90kPa).

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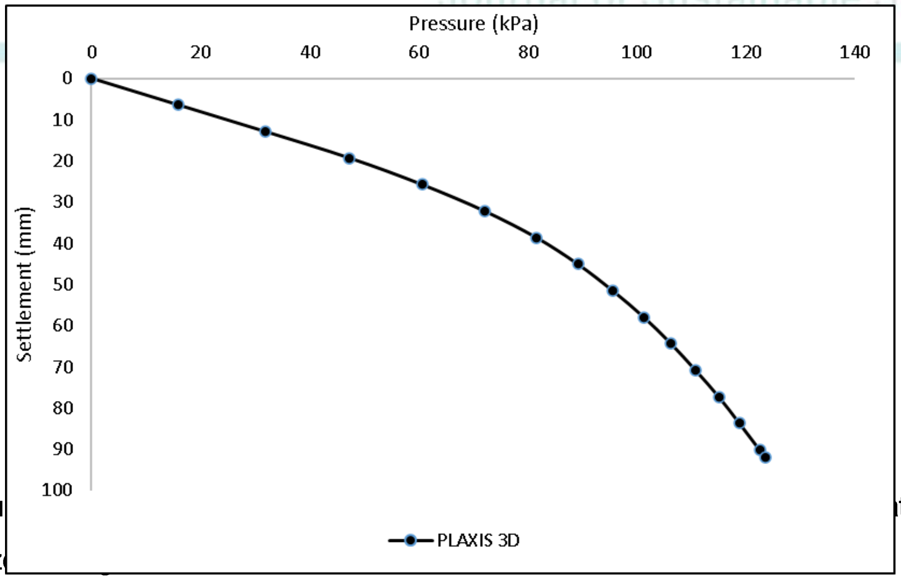

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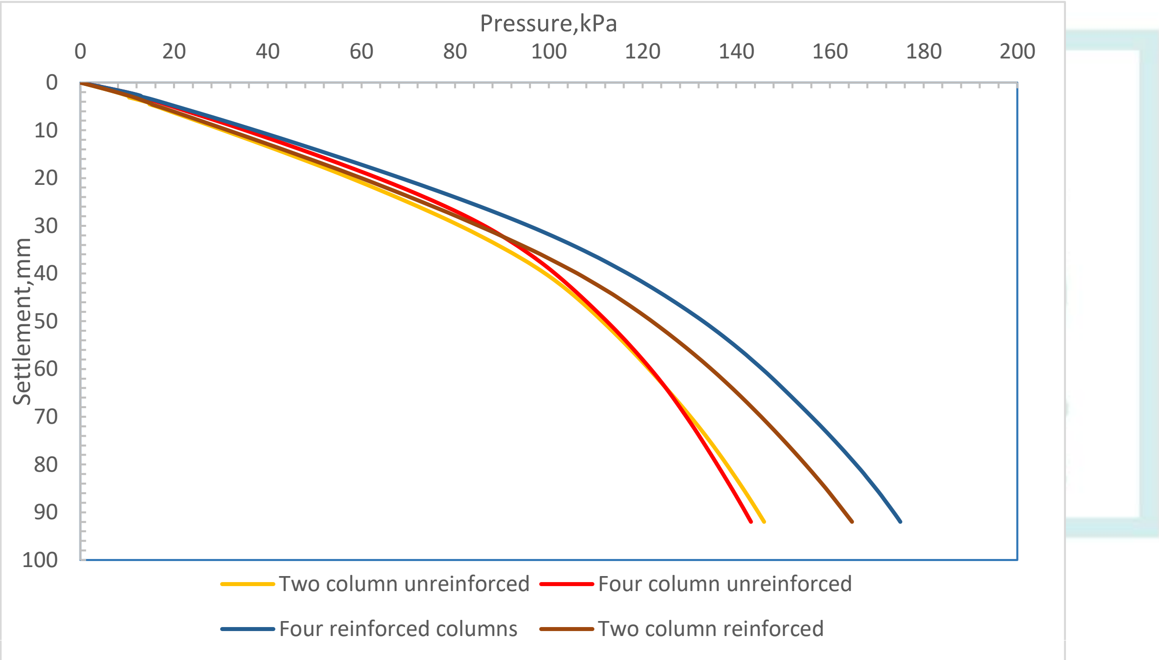
7.2-Unreinforced and Reinforced Recycled Concrete Aggregates (RCA) Columns

Take note of Figure 12 When building two stone columns, the spacing between them should be 50 cm. In the soft clay bed, we find an increase in final bearing capacity of 105 kPa. The hardness of the stone, the rise in the lateral confinement area, the growth in the replacement area, and the expansion of the stress distribution area are all contributing factors.

The diagram shows a modest change between the installation of two columns and four columns, with the ultimate bearing capacity reaching 105 kPa. We discover a clear and unambiguous convergence between the field and numerical results, indicating that the field results are accurate. The reinforced stone columns are no exception.



8. 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 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

9. **References**

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