# STUDY ON STRESS CONCENTRATION RATIO OF STONE COLUMN REINFORCED SOFT CLAY

**Juby Paul[1], Sindhu A.R[2]**

[1]*P.G. Student, Department of Civil Engineering, Saintgits College of Engineering, Kerala, India*
[2]*Assistant Professor, Department of Civil Engineering, Saintgits College of Engineering, Kerala, India*

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**Abstract –** *The construction industry grows at a drastic rate due to increased population. As lands with good bearing capacity are being limited, a proper ground improvement technique is required. Stone column is one of those adoptable methods to densify deep soil strata. Stress concentration ratio (n) is an important parameter used in the design of stone column. So an experimental method to determine the n value is developed. An experimental model test setup is being constructed to study the variation of stress concentration ratio of Stone columns of varying l/D ratios and numbers. The patterns of arrangement of columns were also taken into account. The n value was found to increase as the number of columns was increased. Also, an l/D ratio of 6 showed more n value than an l/D of 5. Also triangular pattern of arrangement showed more n value than square pattern.*

***Key Words*: Ground improvement, Stone column, Stress concentration ratio, model study.**

## 1. INTRODUCTION

Due to rapid increase in population, our construction industry shows a drastic increase. But the lands available for these constructions may not always posses soil of good bearing capacity. Due to unavailability of lands with good bearing capacity, we are forced to build structures on available lands. In such cases, the chances for the structure to collapse are more. Kuttanad region of Alappuzha district posses mainly clayey soils of high compressibility, low bearing capacity and so, acres of land get wasted in these areas. For the construction to be safe, stable and serviceable, the ground should be improved by adopting an appropriate ground improvement technique. Improvement of load carrying capacity will make them suitable for commercial as well as residential purposes. Of many among the ground improvement technique adopted, stone column is usually adopted for deep soil strata.

It densifies the soil, thereby improving its load bearing capacity and reducing settlement. The major design parameters used in the design of stone columns includes, its length to diameter ratios, pattern of arrangement, number of columns, area replacement ratio and stress concentration ratio. Numerous model studies on the determination of load settlement behavior of stone column have been conducted so far. Stress concentration ratio (n) is defined as the ratio of stress in stone column to the stress in surrounding soil for equal settlements.

Here, an experimental method will be discussed to determine the n value of clay reinforced with stone columns of varying length to diameter (l/D) ratios and also by varying the number of columns. l/D ratios of 5 and 6 are adopted and number of columns are so provided to ensure a square or triangular pattern of arrangement.

## 2. LITERATURE REVIEW

In a work conducted by H. K. Sarvaiya and C. H. Solanki, studied the effect of geosynthetics on floating stone columns. Four different types of geosynthetics were used in the study. Four different types of woven Geosynthetic fabrics namely HDPE monofilament, TF-41, TF-422 and TF-52J were used. Load settlement behavior of stone column with these reinforcements were carried out and found that casing is to be provided to ordinary stone column upto its half length. Another work done by Ajay, P.M.S.S.Kumar, studied the settlement characteristics of stone column reinforced soft clay for ground improvement. The Compactive effort of these stones on the load settlement behavior and also effect of geogrid casing were also discussed and found that geogrid casing reduced settlement by 50%. Mohammed Fattah, Kailas Shlash and Maki J introduced an experimental method to determine the stress concentration ratio of stone column. Varying length to diameter ratios were studied of which it was found that as length to diameter ratio was increased, stress concentration ratio value was found to increase.

Samuel Thanaraj, P, M Freeda and Brema J conducted a review on the performance of different types of stone columns in soil stabilization. Reviews on different types stone column materials, stone columns with and without casing and numerical modeling studies were conducted. Tandel Y K, Solanki C H, Desai A K studied the effect of geosynthetics as casing for stone column. Stone column of varying diameter were studied (50mm, 75mm, 100mm). 3D numerical analysis was also performed.

A. M. Hanna, M. Etezad and T. Ayadat studied the mode of failure of stone column in soft clay. Experimental study followed by validation using plaxis 3D was conducted. An extensive literature survey was also conducted. Karun Mani and Nigee K studied the variation of settlement of soft clay stabilized with stone column by varying its diameter and length along with a change in stone column number. Liu Xueyi, Ammar A M, Lin Hongsong and Ren Juanjuan conducted model test on clayey soil reinforced with stone column group. They also conducted FEA for 9, 13 and 23 groups of columns. The effect of area ratio was also studied.

## 3. MATERIALS

The soft clay sample or the test was collected from Kainakery, Alappuzha district of Kerala, from a depth of 3 to 4 m from ground level. Stone aggregates of diameter 2mm to 4.75mm were also collected from Alappuzha district. The collected soil sample were tested for initial moisture content, specific gravity, Atterberg's limit, standard proctor test and grain size analysis in accordance with IS specifications.

**Table -1:** Properties of collected clay sample.

| Properties | Values |
|---|---|
| Initial moisture content | 125% |
| Specific gravity | 2.41 |
| Percentage of gravel | 2 |
| Percentage of sand | 10 |
| Percentage of silt | 42 |
| Percentage of clay | 46 |
| Liquid limit | 136% |
| Plastic limit | 59% |
| Plasticity index | 77% |
| Soil classification | CH |
| Maximum dry density | 1.35g/cc |
| Optimum moisture content | 31% |
| Specific gravity of stone aggregates | 2.63 |

## 4. METHODOLOGY

### 4.1 Model test tank and loading arrangement

A model test tank of 600mm x 600mm x 550mm was modeled using mild steel plate of 3mm thickness. Proper anchorages were provided wherever required. Load was applied manually. Two proving rings were arranged such that each one shows the load taken by stone column and the combined load taken by the stone column and clay sample. Dial gauges were also provided in order to note the settlement. Load is applied up to a settlement of 60% of stone column diameter that is up to a settlement of 18mm.

### 4.2 Stone column and base plate

The stone column length, pattern of arrangement etc was chosen in accordance with IS 15284 Part 1 – 2003. An l/D greater than 4 was chosen to ensure bulging failure only. Therefore, stone column with l/D of 5 and 6 was taken for the study. Stone column diameter was fixed as 30mm and length of 150mm and 180mm were adopted to ensure an l/D of 5 and 6. The number of columns was varied as 1, 2, 3, 4 and 6. Two different pattern of arrangement were studied – namely square and triangular. Base plate of 5mm thickness was provided with holes of diameter equal to the number of columns for that particular test is made. Inorder to measure the load taken up by the column alone, base plate of 12mm thickness with column diameter was cut and placed over the stone column. In case of stone columns more than two in number, these circular base plates are connected to another plate such that load taken by stone column can be measured.

### 4.3 Clay sample bed preparation and stone column installation

The clay was filled in field condition. It was filled in layers of 50mm thickness with proper tamping. The soil bed was leveled at the top. PVC pipe of 30mm inner diameter was installed at the point where stone column is to be installed. The sample inside the pipe was then removed and stone column was filled in layers with proper tamping. The PVC pipe was taken out after each layer installation of the stone aggregate.

**Fig 1 :** Model test tank and loading arrangement

**Fig 2 :** Base plate used for the testing of Three stone column

## 5. RESULTS AND DISCUSSIONS

The tests were conducted and the results were tabulated. The stress concentration ratio values were determined and it was found that the value of n increases as length to diameter ratio was increased and also as the number of columns was increases n value shows an increase. The value of stress concentration ratio obtained is tabulated.

**Table -2:** Stress concentration ratio values.

| Number of columns | l/D = 5 | l/D = 6 |
|---|---|---|
| 1 | 1.94 | 1.84 |
| 2 | 2.03 | 2.17 |
| 3 | 2.39 | 2.5 |
| 4 (square) | 2.99 | 2.93 |
| 4 (triangular) | 3.92 | 3.29 |
| 6 (square) | 4.1 | 3.36 |
| 6 (triangular) | 5.1 | 4.61 |

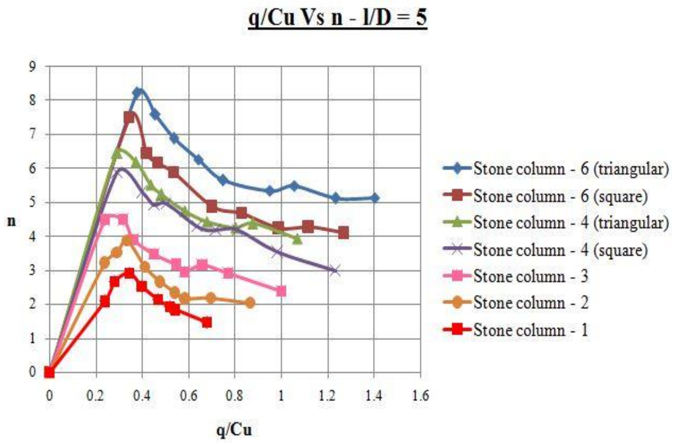


**Chart 1 :** Bearing capacity ratio versus n for l/D =5

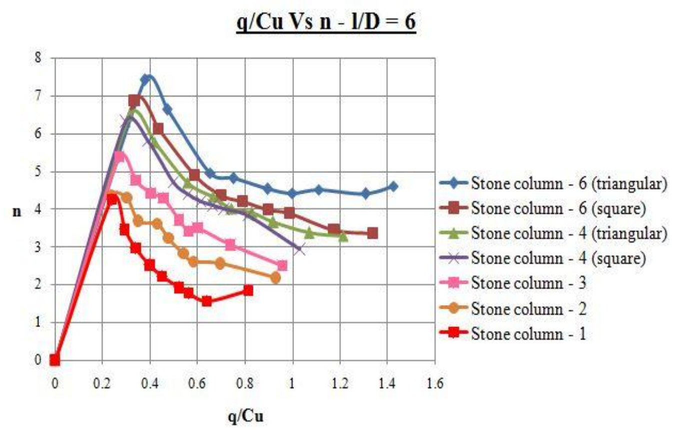


**Chart 2 :** Bearing capacity ratio versus n for l/D =6

Bearing analysis was also conducted. It was found that a plot of bearing capacity ratio versus stress concentration ratio shows an increase as the number of columns was increased from 1 to 6. In that case also the clay sample reinforced with four stone columns arranged in triangular pattern shows a greater n value compared with the same for a square pattern of arrangement.

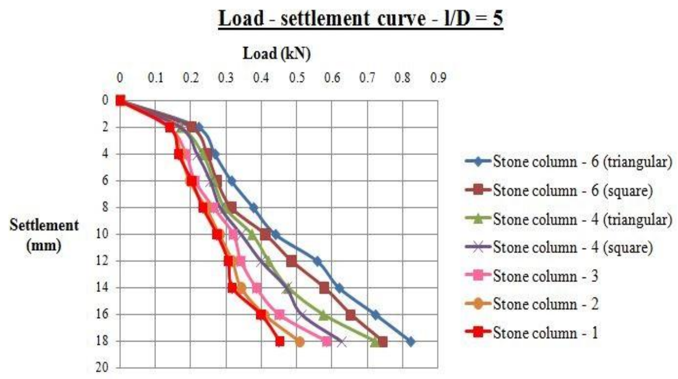


**Chart 3 :** Load settlement curve for l/D = 5

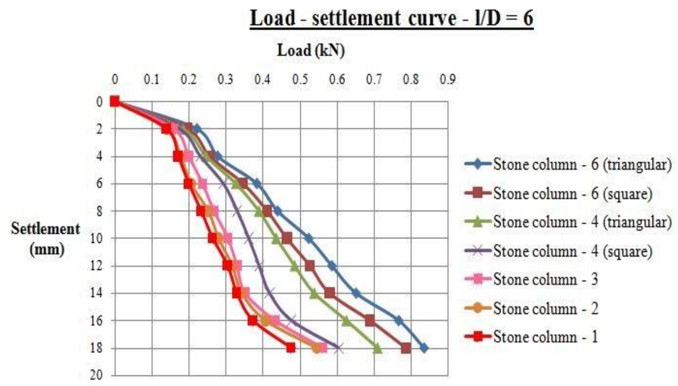


**Chart 4 :** Load settlement curve for l/D = 6

Load settlement curve was also plotted. It was found that, for equal settlement of the stone column and clay sample, the load taken by each column increases as the number of stone column was increased.

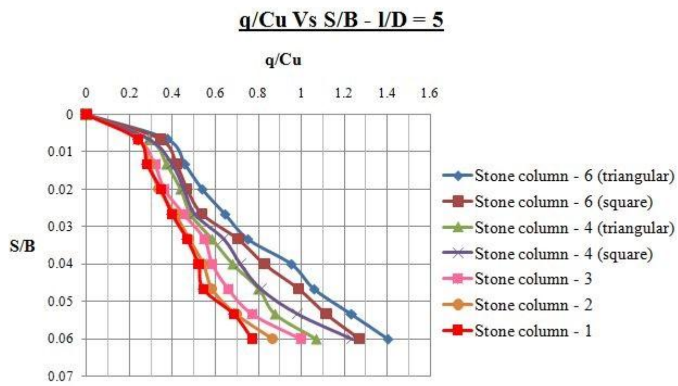


**Chart 5 :** Bearing capacity ratio versus settlement ratio for l/D = 5

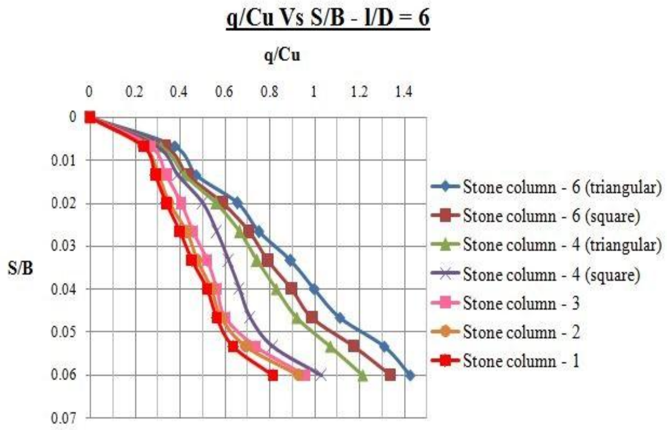


**Chart 6:** Bearing capacity ratio versus settlement ratio for l/D =6

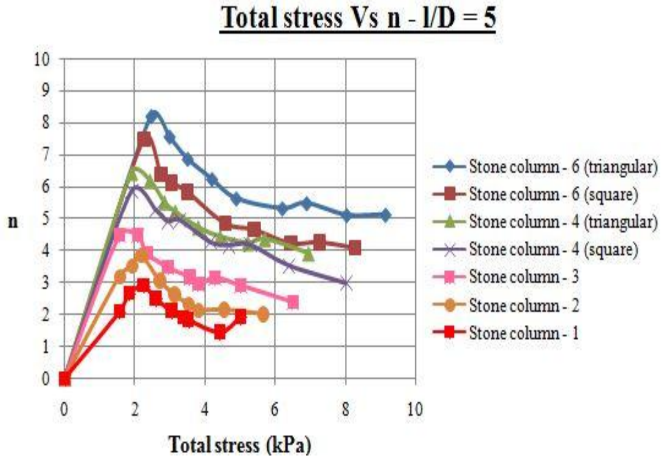


**Chart 7 :** Total stress versus stress concentration ratio for l/D = 5

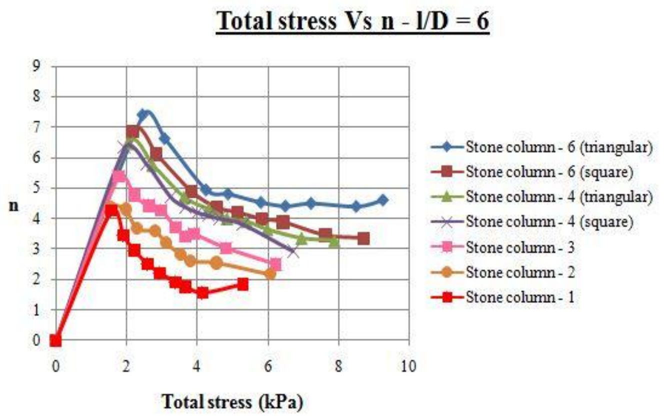


**Chart 8 :** Total stress versus stress concentration ratio for l/D = 6

Based on the values obtained, a graph was plotted with stress concentration ration versus the total stress taken by the stone column and clay sample. Here n value showed a sudden increase then n value was found to decrease as the total stress taken increases.

## 6. CONCLUSIONS

- The value of stress concentration ratio decreased as the length to diameter ratio increases i.e, the value of n for an l/D ratio of 5 was found to be more than the value of n for an l/D of 6.
- Also, as the number of columns was increased from 1 to 6, the n value increases.
- The value of n for clay reinforced with four stone column arranged in triangular pattern shows a greater n value than one in square pattern. The same was observed when the number of columns was 6.
- The value of n decreases as bearing capacity ratio and total stress increases.

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## BIOGRAPHIES

JUBY PAUL
PG Student
Dept. of Civil Engineering
Saintgits College of Engineering
Kottayam, Kerala

SINDHU A R
Assistant Professor
Dept. of Civil Engineering
Saintgits College of Engineering
Kottayam, Kerala