Research Article

A Study On Effects Of Diameter On Stress Response Of Floating Stone Column

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Abstract : This research aims to examine the effect of the diameter of the floating stone column on stress-settlement response. The laboratory experiments are performed with varying diameters from 45 mm, 50 mm, 55 mm, and 60 mm with a fixed length of 300 mm of floating stone column to find the corresponding stress-settlement response. This research finding shows that the stress response decreasing with the increasing diameter of the floating stone column. It shows that the stress-settlement response of the smaller diameter of the floating stone column is effective than the larger diameter of the floating stone column. This research is very helpful in the geotechnical engineering field where ground improvement work is required in the form of a stone column.

Keywords: Floating stone column, stress-settlement response, load carrying –capacity, unit-cell, UCS

INTRODUCTION

The soil with less bearing capacity such as soft soil needs certain attention before doing construction on it. These types of soi are very weak in the load-carrying capacity and higher the settlement. There are plenty of methods available to improve such soil Barron R. A. (1948), Chu, J. (2006), Greenwood D. A., (1970). Sometimes the cost of treating such soil increases the cost of actual construction work. Hence it is the need for such research which can effectively increase the load capacity of such soil and reducing the cost of the project. The stone column is one of the best techniques to increase the strength of soft soil effectively Hughes J. M. O. (1974), Lee J. S. (1998), Pradip Das (2013). In this research, the effect of varying diameters from 45 mm, 50 mm, 55 mm, and 60 mm of the floating stone column on the stress-settlement response is studied. The length of the stone column is kept constant as 300 mm. The results are plotted as stress vs settlement response graphically.

EXPERIMENTAL CONSIDERATIONS

A unit-cell idealization is used for the present study to simplify the actual phenomenon working behind the stone column method. The actual field stone column installation there to scale down to understand the exact behavior of the stone column in the laboratory as shown in figure 2. The laboratory unit-cell is modeled as a cylindrical steel tank having rigid and smooth inside boundary so that when a stone column is installed in the middle of a unit cell is represented as symmetry in all directions. The area influencing the stress due to the installation of the stone column is considered a unit-cell area. There is a no-stress beyond the boundary of the unit cell tank. This concept is used to predict the load settlement behavior of stone columns (Ali K. 2012, Ambily A. P 2007, Bora, Mukul C. 2010, Shivashankar R., (2011), IS 15284-part 1- 2003).

According to IS 15284 (part 1): 2003, the influence of load is within the equivalent diameter. The triangular pattern is considered to design the unit cell tank. A cylindrical unit-cell tank of 300 mm diameter and 600 mm height is used for load tests on a single stone column.

MODELING CONSIDERATION

The model test setup was designed similarly as done by Ambily AP 2007 and Gniel J. 2009. Important details related to boundaries, dimensions, materials, and loading conditions in the model are given due consideration as presented subsequently. A typical prototype stone column diameter varies from 0.6 to 1.0 m and length from 5-20 m. usually; the L/D ratio in the prototype stone column varies 5 to 20, in which L and D are the column length and diameter respectively. Based on this, the L/D ratio in the model test was adopted from 3 to 10. The model tank boundary for load tests was selected on the unit cell-based approach.

In the field, stone columns are formed at a typical diameter (d) range of 0.6 to 1 m, with a typical particle size (D) range of 25 to 50 mm, so that the ratio d/D typically lies between 12 to 40 (3). The column diameters used in the present model tests are 60 mm and the stone column aggregate of size passing from 10 mm and retained from 2 mm sieve size were used to prepare the stone column. The mean particle size (D50 = 1.5 mm) is used for the construction of the model stone column. The ratio d/D (column diameter/ mean particle size) in present model tests is 36.67 (corresponding to column diameter 60 mm).

MATERIALS PROPERTIES

The soil used is of CL type based on modified soli classification system and collected at a depth of 2 m, from SVNIT college campus, Surat, Gujarat, India. Collected clay was air-dried and pulverized. The pulverized clay was sieved through a 2 mm sieve for easy mixing and quicker hydration. The particle size distribution is shown in fiure 1. A series of undrained shear strength tests were carried out to determine the water content corresponding to undrained shear strength 30 kPa of clay. The resulting water content of the clay was found to be 30%. This amount of water content was kept the same in all tests. Other properties of clay soil are given in table 1.

Table 1: Properties of clay

Classification (IS: 1498-1970)	: CL
Specific Gravity	: 2.6
Liquid Limit (%)	: 45
Plastic Limit (%)	: 20
Plasticity Index (%)	: 25 (Medium Plastic)
Clay Content (%)	: 35
Silt Content (%)	: 60
Max. Dry Density (kN/m^3)	: 17
Optimum Moisture Content (%)	: 18
Undrained Shear Strength kPa	: 30
Bulk unit weight at 32% water content	: 18.5 kN/m^3

Crushed stones (aggregates) of size below 10 mm have been used to form a stone column. The aggregate size distribution is shown in Figure 1. The finer fraction passing through 2 mm was removed by sieving and used after air drying. Typical properties of aggregate used as stone column material are summarized in table 2.

Table 2: Properties of stone column material

The angle of internal friction (Deg.)	: 42°
Particle size mm	: 2-10 mm
Uniformity coefficient	: 2
Coefficient of curvature	: 1.125
Specific gravity	: 2.75
Dry unit weight kN/m^3	: 18.5
Unified classification system	: GP

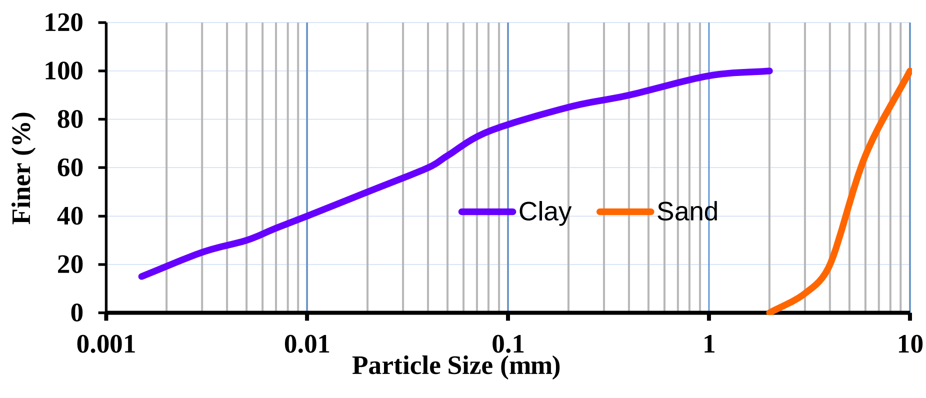

Figure 1: Grain size distribution of clay and stone aggregate for laboratory model test

PREPARATION OF CLAY BED

A series of unconfined compressive strength (UCS) tests are carried out on cylindrical specimens with a diameter of 38 mm and height of 76 mm to determine the moisture content corresponding to clay undrained shear strength of 30 kPa. The resulting water content of the clay is found to be 30%. This amount of water content is kept the same in all tests.

In all the tests, the identical technique is adopted to prepare the clay bed. To maintain similar properties throughout the tests, a clay bed is prepared at 30% water content. The bulk unit weight at 30% water content is found to be 18 kN/m3. Before filling the tank with clay, a thin coat of grease at the inner surface of the tank wall is applied to reduce the friction between the clay and the tank wall. The soil is filled in the tank in 5 layers with measured quantity by weight. Each layer was subjected to uniform compaction by hand to achieve 120 mm height and the corresponding unit weight. The stone column is constructed by the replacement method. Thin open-ended seamless steel pipes of 60 mm outer diameter and wall thickness 2.5 mm are used to construct the stone column. The outer surface of the pipe is lubricated by applying a thin layer of grease for easy penetration and withdrawal without any significant disturbance to the surrounding soil. For an ordinary stone column, a casing pipe is pushed into the soil along with a base plate having a circular groove to accommodate the casing pipe to prevent the soil from entering the pipe during the installation. When the casing pipe is pulled out, the base plate remains in the soil. Stones aggregates are charged into the hole in layers in measured quantities to achieve a compacted height of 120 mm. The pipe is then raised in stages ensuring a minimum of 5 mm penetration below the top level of the placed gravel. To achieve a uniform unit weight, compaction is done with a 2 kg circular steel bar with 10 blows of 100 mm drop to each layer. This light compaction effort is adopted to ensure that there is no significant lateral bulging of the column which creates a disturbance to the surrounding soft soil. The unit weight of stone columns is estimated with the quantity of aggregate consumed for the construction and the volume of the stone column. The corresponding unit weight of the stone column was found to be 18 kN/ m3. The procedure was repeated until the column was completed up to the full required height.

TEST PROCEDURE

A typical laboratory test arrangement for floating stone column is shown in Figure 3. All the experiments are conducted on floating stone columns in homogeneous clay beds in unit cell tanks. Murugesan (2009), Shivakumar (2004), Wood et al. (2000), Ambily (2007), Barksdale (1983) have performed laboratory model tests on the stone column installed in a unit cell tank. The stress-settlement behaviour of floating stone column has been studied by applying the vertically load over it with the help of triaxial testing machine as shown in figure 3.

If stone columns are evenly distributed, a regularly shaped area around the stone column may be considered as “Unit cell”, consisting of stone column material and the surrounding soft soil in a zone of influence shown in figure 2. To simplify the analysis the zone of influence is approximated by a circle with a diameter De equals to 1.05S, and 1.13S for triangular and square pattern respectively, where S is the center to center spacing of stone column.

The vertical load was applied through a triaxial testing machine at constant displacement rate of 0.24 mm/min. the displacement rate chosen so as to avoid any possibility of squeezing out of soil particle from the clay bed and to avoid the generation of extra pore pressure in the clay bed. The approx. 5 mm seating load was applied before counting the actual settlement. The steel plate of 10 mm thickness and diameter equals to the diameter of stone column was used to transfer the uniformly distributed load over stone column. The plate was directly rested over the stone column and the uniform loading was applied over the steel plate. The corresponding deformation is measured with the help of LVDT.

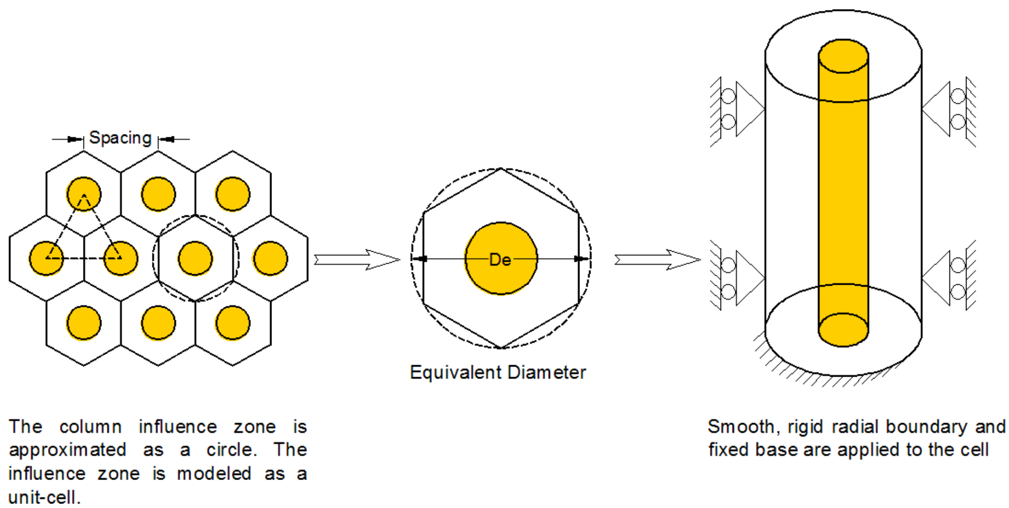

Figure 2: Unit cell Idealization (Ref: Gniel and Bouazza 2009)

The stone column was constructed by a replacement method. After the soft soil bed was prepared, a casing pipe having an outer diameter equal to the diameter of the stone column was used to instal the stone column. Thin open-ended seamless steel pipes of varying diameter and 2 mm thick were used in the present study. The casing pipe pushed into the clay bed up to the required depth. In the case of the encased stone column, the encasement was provided around the casing pipe. The only static force was manually applied to push the casing pipe gently into the soil so as to minimize the disturbance in the clay soil that may change the properties of the clay after reinforcement.

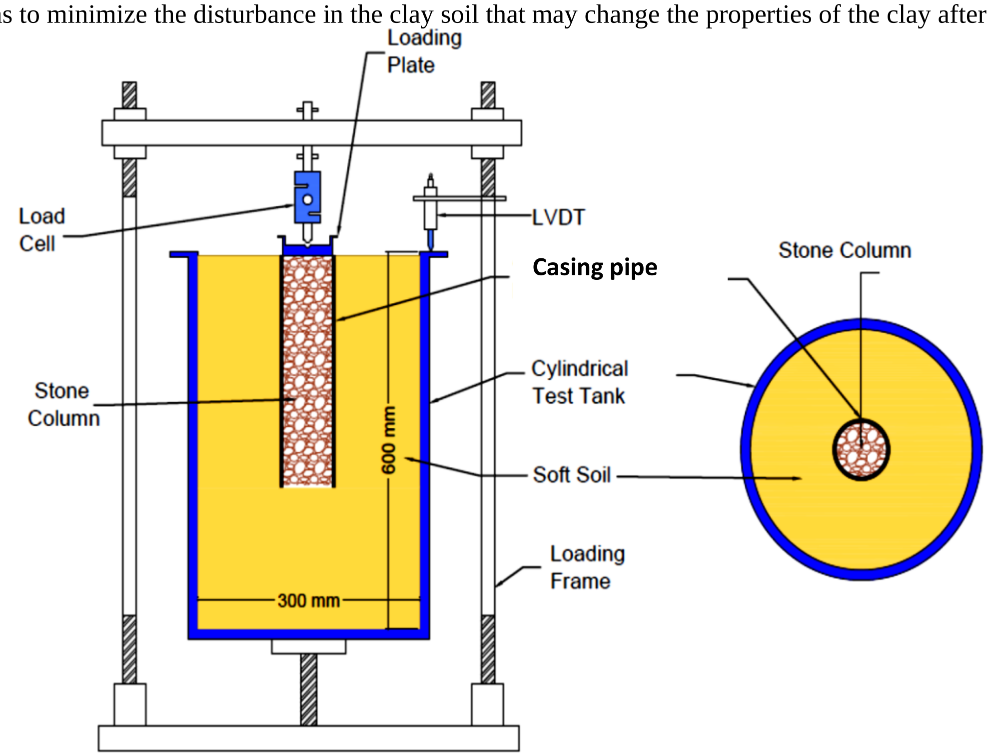

Figure 3: Schematic diagram for load test on single stone column in a unit cell

For applying a load to the floating stone column, a loading plate corresponding to the column diameter is used for the same as the diameter of the stone column. The plate is exactly placed over the stone column at the center of the stone column and the load is applied for up to 40 mm settlement. Figure 4 shows the results obtained by performing a laboratory test to know the effects of varying diameter on the stress-settlement behavior of the floating stone column.

The outer surface of the pipe was lubricated by applying a thin layer of grease for easy withdrawal without any significant disturbance to the surrounding soil. The stone column aggregate material soaked for 24 hours before charging into the casing pipe in order to prevent it from absorbing the moisture from the surrounding clay soil. The stone column aggregate material was charged into the hole through casing pipe in layers in measured quantities so as to have each compacted fill layer of 50 mm thickness. A layer was compacted by a 2 kg circular steel tamper with 10 blows of a 100 mm drop to achieve uniform compacted density. This light compaction effort was adopted to ensure that there is no significant lateral bulging of the stone column which may create a disturbance to the surrounding soft clay. The corresponding unit weight was found to be 18.5 kN/m3. The casing pipe was then raised in stages ensuring a minimum of 5 mm penetration below the top level of the placed material. The procedure was repeated until the stone column was completed to the required depth as shown in figure 3.

EXPERIMENTAL PROGRAM

There are series of load tests performed to check the stress-settlement behavior of the floating stone column. Table 3 shows the list of an experiment performed to check the effects of the diameter of the floating stone column on the stress-settlement behavior. To know the effect of the diameter on stress-settlement behavior of floating stone column the length of the stone column is kept constant as 300 mm and the diameter of the floating stone column are changed as 0 mm, 45 mm, 50 mm, 55 mm, and 60 mm as listed in table 3.

Table 3. List of laboratory experiment to find the effects of diameter on stress-settlement behavior of floating stone column

Length of stone column	Diameter of stone column				
300 mm	0 mm	45 mm	50 mm	55 mm	60 mm

RESULTS AND DISCUSSIONS

The laboratory experiments to find the effects of the diameter on stress-settlement behavior of floating stone column is shown in table 3. The diameter of floating stone columns is varying as 0 mm, 45 mm, 50 mm, 55 mm, and 60 mm and the corresponding length is kept constant as 300 mm. The results show a significant improvement in load-carrying capacity by inserting a floating stone column in a clay bed. By increasing the diameter of the floating stone column from 0 mm, 50 mm the stress-settlement response is increasing. By increasing the diameter of the floating stone column from 50 mm to 60 mm the stress-settlement response is decreasing as shown in figure 4. The results obtained from the load test are shown in graphical form. Figure 4 shows the stress vs. settlement responses of the floating stone column with varying diameters. The results are compared well with the untreated soil.

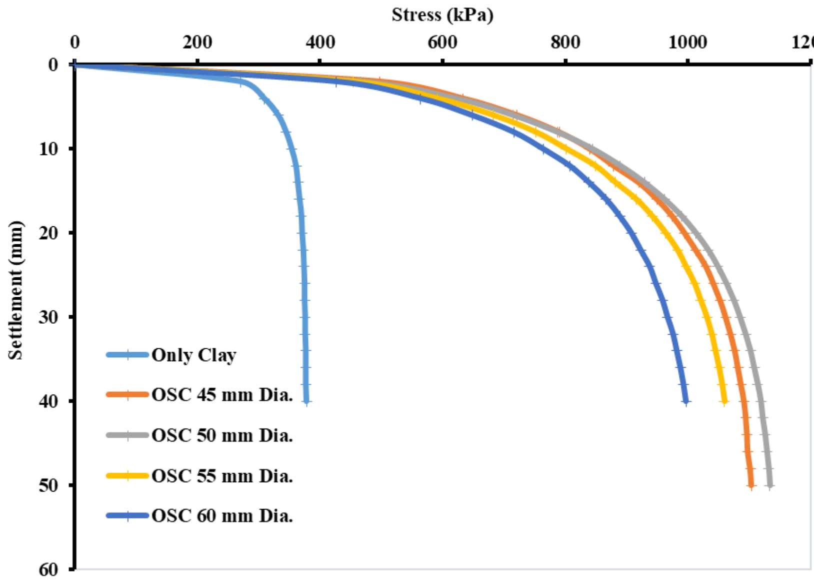

Figure 4: Stress Vs Settlement responses of floating stone column with varying diameters

CONCLUSION

To know the effect of diameter on the stress-settlement response of floating stone column the experimental results show that by inserting the stone column the load-carrying capacity is increasing. The stress response of untreated soil is measured at 40 mm prescribed settlement as 398 kPa. The stress response at 40 mm settlement was measured as 1114 kPa, 1150 kPa, 1050 kPa, and 997 kPa for the diameter of 45, 50, 55, and 60 mm of floating stone column respectively. The stress response improved 2.799, 2.889, 2.638, and 2.505 times higher compared to untreated soil respectively. The stress-settlement response is increased for the stone column diameter up to 50 mm. By further increasing the diameter the stress response is decreased. It shows that the stress response decreases with the increase of stone column diameter. So the slender column is more effective than the thick floating stone column. The effective diameter of the floating stone column is 50 mm diameter.

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