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Research Paper

EFFECT OF GEOSYNTHETIC ENCASEMENT ON SAND COLUMN IN SOFT SOIL

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The soil improvement method mostly used in the current state of the practice with densification, consolidation, reinforcement, chemical treatment and stabilization of soil. Soil reinforcement can be an ideal solution for improvement of clay. Out of other conventional methods, stone columns (or sand columns) are effectively being used for ground improvement, particularly for flexible structures such as road embankments, oil storage tanks, etc. The load capacity of the sand columns mainly depends on the shear strength of the surrounding soft soil. The sand column is found useful in improving load capacity and reducing the settlement of clay deposit. In addition to this, the encasement of geosynthetic all-round the sand columns is suggested for enhancing the load carrying capacity of the sand column in treated ground which also ensures the easy formation of columns in weak strata. The present study investigates the effect of diameters of geosynthetic encased sand columns in soft soil deposit during loading. The load responses of sand columns are also investigated with the variation of encasement length of the column.

Keywords: Geosynthetic encased sand column, Ordinary sand column, Geosynthetic, Bulk unit weight, Relative density, Reinforcement, Soft clay

INTRODUCTION

The techniques for soil improvement have been changing during the last three decades. A lot of soil improvement methods have been used to deal with soft soil problems. The reinforcement of ground by tension resistant elements can be applied for improvement in weak strata. This reinforcement can be provided with stone columns or sand columns. Stone columns, also known as granular piles have been used to a large extend for several applications. Stone columns essentially increase the bearing capacity of soft soils. Therefore, ground reinforcement by stone columns solves the problems of the soft soil by providing advantage of reduced settlement and accelerated consolidation process.

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In case of group of sand columns Bulging is found the primary mode of failure. This drawback can be overcome by wrapping the individual sand columns with a suitable geosynthetic. The geosynthetic encasement helps in easy formation of the sand column and improves the strength and stiffness of the columns. By reinforcing sand columns by Geosynthetic, the ultimate bearing capacity of that column can be increased to considerable amount. Thus the geosynthetic encased sand column is the technique for reinforcement to improve the loading capacity of the ground.

Van Impe and Silence (1986) was probably the first to recognize that columns could be encased by geotextile. The loading capacity improvement and reduction in settlement is possible with a high-modulus geosynthetic encasement of sand columns of gravel columns to avoid bulging (Raithel *et al.*, 2000, Alexiew *et al.,* 2005, di Prisco *et al.*, 2006, Murugesan and Rajagopal, 2006, 2007, 2010, Gniel and Bouazza, 2009, 2010). The results of those research works have been implemented for installation of geosynthetic encased stone columns in various projects.

Malarvizhi and Ilamparuthi (2004) reported the improved performance of geosynthetic-encased stone columns based on small-scale laboratory tests on end bearing as well as floating columns. Murugesan and Rajagopal (2006) reported that the bulging of stone column upon loading will be predominant up to a depth of 1.5-2 times the diameter of stone column from the ground surface. Hence, only the top portion of the stone column needs more lateral confinement in order to improve its performance. The performance of encased stone columns of smaller diameters is superior to that of larger diameter stone columns because of mobilization of higher confining stresses in larger stone columns (Murugesan and Rajagopal, 2006, Kameshwar *et al.*, 2011, Tandel *et al.,* 2012).

Hence this paper investigates the improvement in loading capacity of sand columns in a square pattern after all-round encasement by different types of geosynthetic. This paper represents the load response of different diameters of the encased sand columns in group load test. The effect of encasement length of the sand column is also investigated. The results can be useful to save the cost, effort and time for installation of stone columns.

MATERIALS

Soil

The soil, taken from Vesu in Surat was sieved through 2 mm sieve to remove the coarser fraction. To find the undrained cohesion of the soil sample, laboratory vane shear tests were carried out at 38% and 43% water content (Table 1).

Table 1: Properties of Soil

Property	Value
Liquid limit (%)	48
Plastic limit (%)	18
Plasticity Index (%)	30
Specific gravity	2.50
Indian Standard soil classification	CI
Bulk unit weight at 43% water content (kN/m^3)	17.25
Undrained cohesion at 43% water content (kN/m^2)	9

Sand

The clean river sand aggregates of a size less than 4.75 mm was taken to form sand columns. The sand compacted to a density of 1.62 g/cm^3 and it was maintained constant throughout all the tests (Table 2).

Table2: Properties of Sand

Property	Value
Specific gravity	2.74
Maximum unit weight (kN/m^3)	18.0
Minimum unit weight (kN/m^3)	15.0
Compacted unit weight (kN/m^3)	16.20
Relative density (%)	45
Uniformity coefficient	3.50
Coefficient of curvature	0.73

Geosynthetic

Three types of geosynthetic material have been used for the experimental program. The materials have been sewn and glued to provide a circular shape for encasement purpose. The results of the initial tensile modulus of geotextile and geogrid was taken by wide-width tensile test (ASTM D4595) (Table 3).

Table 3: Properties of Geosynthetic

Types of Geosynthetic	Initialtensile Modulus (kN/m)
Soft grid	7.50
Non-woven geotextile	11.50
Woven geotextile	43.70

METHODS

The laboratory tests were conducted on two different diameters 50 mm and 75 mm of sand columns in order to predict the influence of sand columns during group load test. The other parameter, the initial modulus of the geosynthetic was varied by using three different types of geosynthetic as woven geotextile, non-woven geotextile and geogrid for the encasement. The sand columns were installed in the soil bed with a typical square pattern.

Preparation of Soil Bed

The laboratory vane shear test resulted to the undrained cohesion of soil 9 kN/m^2 at 43% water content. The proper mixed soil mass with corresponding water content was placed at each 5 cm up to the full height of 40 cm in the tank of size 50 cm × 50 cm × 45 cm.The surface of each 5 cm layer was provided with uniform compaction up to the full depth of soil layer in the tank.

Installation of Sand Columns

The sand columns of four in numbers were installed up to full depth of soil layer in a square pattern of spacing 25 cm center to centre of each sand column in the tank.

The sand columns in the experimental work were installed by displacement method using a casing pipe having an outer diameter equal to the diameter of the sand column. The encased sand columns were installed by wrapping the geosynthetic around the casing pipe. The casing pipe along with a base plate was pushed into clay bed vertically at the specified location in the clay surface till it reaches the bottom of the tank. The base plate is to prevent the surrounding clay from entering into the pipe during the lowering of casing pipe. The displaced clay was taken out and the surface of the soil was trimmed to its original level.

The quantity of the sand aggregate required to form the stone column was pre measured and charged into the casing pipe in layers of 5 cm thickness up to the full height of sand column. The relative density of sand was maintained at 45% for the installation of each sand column.

Load Test on Sand Column Group

After installation of sand columns the entire tank set up is placed in the loading frame and the loading is applied through strain controlled displacement of loading plate at a constant strain rate of 1.2 mm/min. The settlement in the sand column group was measured with the help of LVDT (Figure 1).

Figure 1: The Loading Frame with LVDT in Laboratory

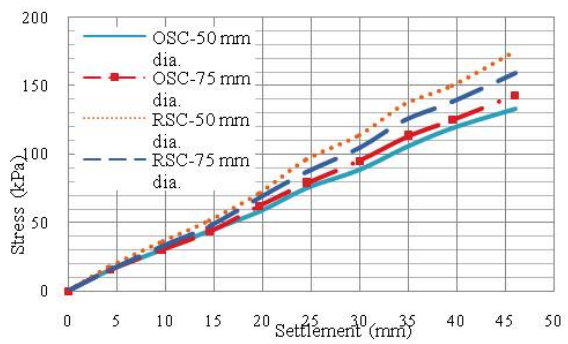
RESULTS AND DISCUSSION

Effect of Diameter of Sand Column

For a given Stress of 100 kPa and Column Encased With Soft Grid, OSC Having 50 mm diameter, has Settlement 34 mm and for OSC Having 75 mm diameter, has Settlement 32 mm. For RSC Having 50 mm diameter, has settlement 25 mm and for RSC having 75 mm diameter, has settlement 28 mm. Which Means in case of OSC settlement is less in 75 mm diameter Whereas in case of RSC it is opposite 75 mm diameter have more settlement (Figure 2).

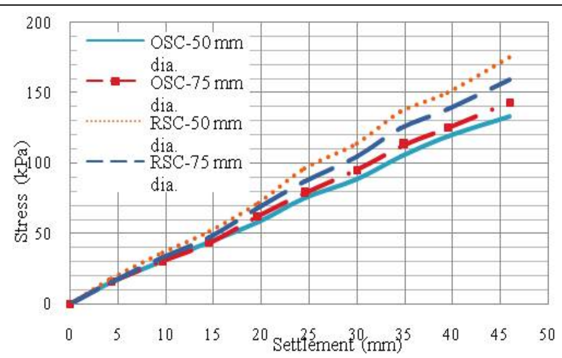
Hence, in case of OSC, the 75 mm diameter column has 6% less reduction in settlement than 50 mm diameter of sand column. In case of RSC (Soft grid), the 50 mm diameter column has 10% less reduction in settlement than 75 mm diameter of sand column for a given stress of 100 kPa.

Figure 2: Stress-settlement Response Of Sand Columns Reinforced With Soft Grid For 100% Reinforcement



For a given Stress of 100 kPa and column encased with Non-Woven Geotextile, OSC having 50 mm diameter, has settlement 34 mm and for OSC having 75 mm diameter, has

Figure 3: Stress-Settlement Response Of Sand Columns Reinforced With Non-woven Geotextile For 100% Reinforcement



settlement 32 mm. For RSC having 50 mm diameter, has settlement 20 mm and for RSC Having 75 mm diameter, has settlement 23 mm. Which means in case of OSC settlement is less in 75 mm diameter, whereas in case of RSC it is opposite 75 mm diameter have more settlement (Figure 3).

Again, in case of RSC (Non-woven), for a given stress of 100 kPa, the 50 mm diameter column has 13% less reduction in settlement than 75 mm diameter of sand column.

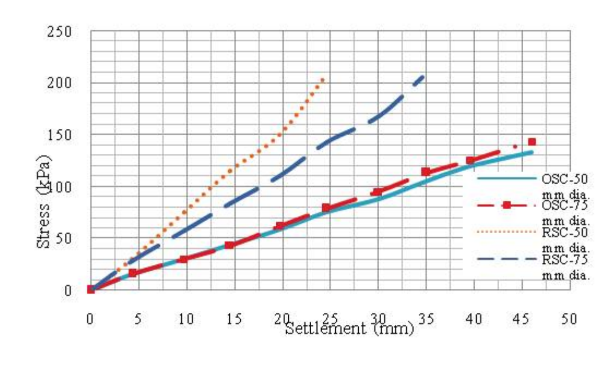
For a given Stress of 100 kPa and Column Encased with Woven Geotextile, OSC having 50 mm diameter, has settlement 34 mm and for OSC having 75 mm diameter, has settlement 32 mm. For RSC having 50 mm diameter, has settlement 12.5 mm and for RSC having 75 mm diameter, has settlement 17.5 mm. Which means in case of OSC settlement is less in 75 mm diameter whereas in case of RSC it is opposite 75 mm diameter have more settlement (Figure 4).

In case of RSC (Woven), for a given stress of 100 kPa, the 50 mm diameter column has 28% less reduction in settlement than 75 mm diameter of sand column.

There is significant reduction of settlement with increase in initial tensile modulus of geosynthetic material. So the increase in initial modulus of geosynthetic for encasement can improve the performance of sand column.

The settlement response shows that for OSC as the diameter increases, the Stress is also increases, whereas in case of RSC (Soft Grid), RSC (Non-Woven), and RSC (Woven) geotextile the pattern is opposite, that is with increase in diameter stress is decreasing, the only thing is that in case of RSC (Woven) geotextile the diameter is more dominant.

Figure 4: Stress-Settlement Response Of Sand Columns Reinforced With Woven Geotextile For 100% Reinforcement



Effect of Encasement Length of Sand Column

The effect of reinforcement length on the load carrying capacity of the reinforced sand column for 50 mm and 75 mm diameter is sand column is discussed in this section. The variation of stress corresponding to 20 mm settlement for different types of geosynthetic and different types of reinforcement length is drawn (Figure 5). It can be conclude that as the reinforcement length decrease load carrying capacity of reinforced sand column

Figure 5: Variation of Stress Corresponding to 20mm Settlement For 50mm Diameter Sand Column

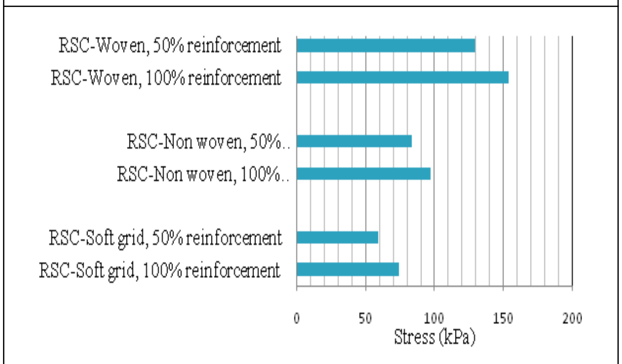
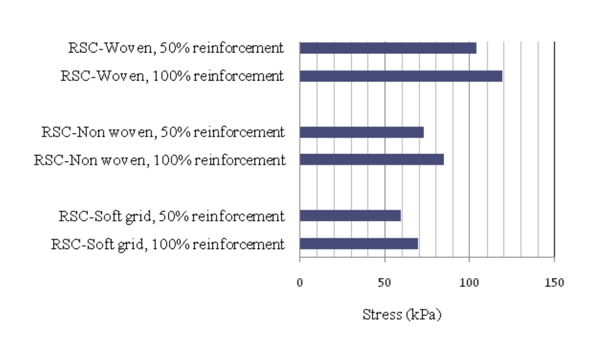


Figure 6: Variation of Stress Corresponding to 20 mm Settlement for 75 mm Diameter Sand Column



get decreases for different types of reinforcement. But the decrease in the load carrying capacity from 100% reinforcement to 50% reinforcement length is not significant. This suggests that, 50% reinforcement (4 times the diameter of column) may be adequate as per the result form the present study.

CONCLUSION

The performance of smaller diameter sand column is superior to that of bigger diameter sand column. The reason for this is the development of larger additional confining stresses in smaller diameter reinforced columns. Increasing the initial modulus of geosynthetic for encasement of sand column, there is more improvement in performance of that column. The encasement up to the 4 times the diameter of sand column can be adequate to increase the performance of the sand columns.

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