THOMSON REUTERS ENDNOTE

[George* *et al.*, 5(8): August, 2016] ISSN: 2277-9655
IC™ Value: 3.00 Impact Factor: 4.116

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

STUDIES ON THE EFFECT OF SPACING OF COIR GEOTEXTILE ON LIME STABILISED QUARRY WASTE COLUMN

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DOI: 10.5281/zenodo.60807

ABSTRACT

Stone columns are massively used ground improvement technique. Installation of stone columns enhances the load carrying capacity and accelerates consolidation and thereby reduces settlement. The lateral confinements offered by the surrounding soil are inadequate to form the stone column, when installed in extremely soft soils. In such cases, the performance of stone column can be improved by lateral reinforcements. Here coir is provided as the lateral reinforcement. The present study investigates the load verses settlement response of various spacings of the coir geotextile reinforced lime stabilised quarry waste column. Four different spacings are adopted. The results revealed that the load carrying capacity of stone column is influeneced by the spacing of the reinforcemnt.

KEYWORDS: Coir Geotextile, Load Carrying Cpacity, Spacing, Stone column.

INTRODUCTION

Due to the constant increasing value of land, the development of marginal sites, once cost prohibitive, has become economically feasible. The rising cost of conventional foundations and various environmental constraints greatly encourage the in-situ improvement of weak soil deposits. A number of new ground improvement techniques have been recently developed to economically improve the weak soil deposits. Some of these are feasible for present use, but many require considerable additional research. Nevertheless, a crucial need now exist for proven techniques which may be used as environmental friendly and economical alternatives to conventional foundation support systems. Construction of highway embankments using conventional design techniques such as preloading, dredging and soil replacement techniques can no longer be considered as effective methods due to environmental restrictions and post-construction maintenance expenses.

Stone columns are one method of ground improvement having a track history of experience. They are best suited for improving soft clays and silts and also for loose silty sands. The concept was first applied in France in 1830 to enhance a native soil. Among all these methods, the stone column technique is mostly adopted because they furnishes the primary function of reinforcement and drainage [1]. It improves the strength and deformation behavior of the weak soil deposits [2]. Another great advantage is the simplicity of its construction method. Stone column achieve their load carrying capacity by bulging. It thereby induces a near-passive pressure conditions in the surrounding soil. The load carrying capacity of stone column is highly influenced by the characteristics of the surrounding soft clay [3]. Hence the load carrying capacity cannot be increased more than 25 times the strength of soft clay [4]. In such cases the performance of the stone columns itself need to be enhanced by suitable methods.

The performance of the stone column can be improved by three methods such as; a)encasing the stone column; b) lateral reinforcement of stone column and c) by providing granular mat over the column. The geosynthetic encasement imparts lateral confinement and avoids lateral squeezing of the stones in extremely soft soils.But the column encasement has minute effect for an elastic column. It plays its role only after column yielding. The efficiency of the encasement is directly associated to its stiffness. Therefore encasing stone column is advocated in soft soils using stiff encasement and under moderate loads. Because under heavy load, the encasement reaches its tensile strength and does not produce any further improvement [5].

Inclusion of horizontal reinforcement minimizes the bulging of the stone column and thereby reducing settlement. The enhancement of bearing capacity by horizontal reinforcement is related to the stiffness of the material and its spacing [6]. Geogrid is considered as the best material for this purpose. Horizontal reinforcements and lateral encasements exhibits similar performance in case of floating column. But for end bearing columns encasement method is more suitable than horizontal reinforcement. A granular layer of sand or gravel is generally placed over the stone columns for drainage purposes and for the distribution of stresses coming from the superstructure. The mat has a thickness of 30 cm or more. Due to high stress concentration at the top of the pile, bulging and subsequent failure occur at this region of pile. The presence of granular bed highly influences these stresses. The granular mat acts as stress distributor and transfers the applied stress to the depth of the column, where more support takes from the surrounding soil. This reduces the bulging in the column [5].

In the present study, the effectiveness of spacing of natural geotextile reinforcement (coir) in lateral direction on the single floating quarry waste columns is investigated through laboratory strain controlled load test.

MATERIALS AND METHODS

Materials used

Soil

Soft soil sample was collected from Kuttanad region of Kerala. Kaolinite and illite are the fundamental minerals that constitute Kuttanad clay. High compressibility, low shear strength and high percentage of organic matter are some of the characteristics of theses clay. Its properties were determined and are listed in Table 1.

Table 1. ***Properties of soil***

Properties	Value
Natural moisture content	124.5%
Specific Gravity	2.46
Clay fraction	53.57%
Silt fraction	41.69%
Sand fraction	4.74% < 5%
Liquid Limit	127.5 %
Plastic Limit	40 %
Plasticity Index	87.5 %
Soil Classification	Silty-clay (CH-MH)
Optimum Moisture Content	27.5 %
Maximum Dry Density	1.33g/cc
Cohesion (c)	10kN/m^2
Angle of internal friction, ϕ	8°
Permeability	9.63 x 10^{-5} cm/s

Quarry Waste

Quarry dust or crusher dust is acquired as soil solid wastes while crushing of stones to get aggregates. Quarry dust shows higher shear strength which enables it to be used a geotechnical material. It possess good permeability and changes in water content does not significantly influence its desirable properties. Quarry waste is used as a replacement in stone column too. Quarry dust, though a waste product is efficient in enhancing the load settlement properties of soil used and its performance is proportional to that of sand. Because of its cheapness and easy availability, quarry dust may be used economically and effectively for stone column construction [8]. Quarry waste passing 4.75 mm sieve and retained on 452µ sieve was used.The properties of quarry waste are listed in Table 2.

ISSN: 2277-9655
Impact Factor: 4.116

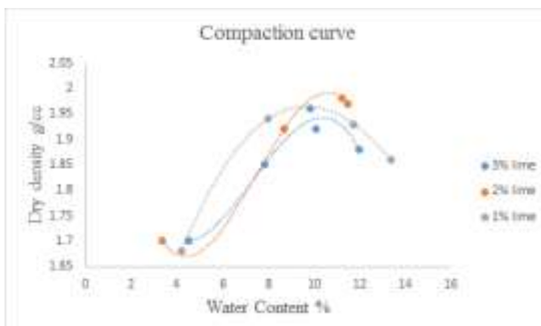
Table 2. ***Properties of quarry waste***

Property	Value
Specific Gravity	2.57
Percentage silt and clay	11%
Percentage fine sand	38%
Percentage medium sand	40%
Percentage coarse sand	10%
Φ	38°
Γ	1.64g/cc

Lime

Lime is an exceptional support in the improvement and stabilisation of soil. Lime can considerably enhance the stability and load carrying capacity of soil. Almost all fine grained soils can be modified with lime, the most substantial improvement occurs in clayey soil of moderate to high plasticity soils. Here lime is added to stabilise quarry waste, which is the filling material of stone column. Lime was added to quarry dust in the increment of 1 % and was compacted in standard proctor apparatus to find the optimum percentage of lime. The lime content which gives maximum dry density was selected as the optimum lime content. 1 2 and 3% of lime was added to the quarry dust and of these 2% was found to be optimum.

Figure 1:



Compaction curve for different percentages of lime

Coir Geotextile

Coir is a coarse rigid and strong, biodegradable organic fibre material. Cellulose and lignin are the main constituents of coir. Coir fibre is resistant to weather, fugal and bacterial decomposition. Compared to any other natural fibre, the rate of decomposition of coir fibre is much less. High lignin content in the fibre contributes to these properties of fibre. In the engineering applications in the geotechnical field, coir in the form of woven mesh mattings or non-woven stich bonded blankets are used. Here H2M6 type of coir reinforcement was used. Its properties are listed in table 3.

Table 3: ***Properties of H2M6 fabric***

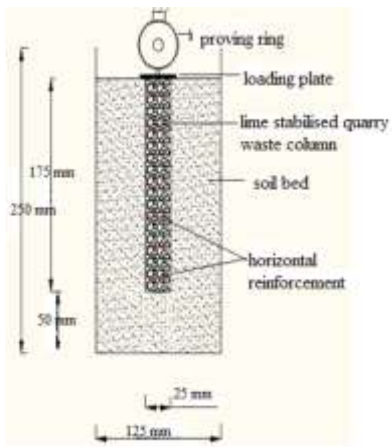
Mass/unit area (gm/m^2)	Thickness (mm)	CBR push Through (kN)	Tensile strength (kN/m)	Mesh size (mm)
454.48	6.55	.71	8	20.07 x 16.87

Methodology

Physical modelling

The model tests are to be conducted on a lime stabilised quarry waste column installed at the centre of clay bed arranged on a cylindrical tank. A loading plate, having a diameter twice as that of column is adopted to transfer footing load to stone column and surrounding soil.The thickness of the soft soil bed is kept unchanged as 225 mm throughout the tests. The mould selected is a mild steel tank with a diameter 125 mm and height 250 mm. It had a wall thickness of 250 mm. The proposed column is a floating long column having a diameter (d) of 25 mm and a length (L) of 175 mm such that it possess a slenderness ratio of 7. The column is made floating by providing a gap equal to twice the diameter of footing between the bottom end of the column and the tank surface. Here 50 mm is given. In order to get an area ratio of 25 %, a footing diameter equal to twice the diameter of the column is provided. Area ratio is defined as the ratio of area of column to area of footing. By this way, the column and the encircling soil is loaded together. A loading plate of 12 mm thick is provided. Schematic diagram of test set up is shown in Figure 2.

Figure 2:



Test set up

Test set up

Prepration of soft soil bed

The wet soil is mixed with water equal to 1.5 times the liquid limit of the soil by crushing thoroughly in a large tank. The slurry so formed, is made sure that it is free of any lumps in order to remove any stress history. This slurry is then transferred to buckets of equal dimensions, with proper drainage. In order to provide drainage, the bottom of the buckets is provided with enough number of holes. It is then filled with 6 mm diameter stones to a height of 50 mm. A sheet of filter paper is placed over the stone bed to prevent the slurry from blocking the drainage path. At the top, over the slurry another sheet of filter paper is provided. A thermocol disc is placed over it. To allow consolidation, dead weights are provided using concrete blocks of 150 mm x 150 mm weighing about 9 kg. For a period of 7 days the consolidation was continued, till the water content of the clay bed reduced to 85% to 95%. Thus clay beds of uniform water content and consistency are achieved throughout the test. The inner surface of the tank is coated with silicone grease, before filling the soil into the tank. This is done to avoid side wall friction. Soil bed is constructed by blending with hand without entrapping any air bubbles. A PVC pipe of 25 mm diameter is placed at the required level, at the centre of the tank. During the process of filling, the clay layer is moulded mildly by hand to expel air. The clay bed thus made covered with wet jute and left for 24 hours for thixotropic gain.

Construction of lime stabilized quarry waste column

After 24 hours, the PVC pipe is removed from the clay bed without making any disturbance to the bed. Using a funnel, the quarry waste mixed with optimum amount of lime needed to form the column is carefully discharged into the hole in 3 layers. Using a 12 mm diameter rod, each layer is compacted to achieve a density of 1.5 g/cc. The composite soil with quarry waste column is covered with wet jute and left for 24 hours. This was to done to develop proper bonding between the column and the bed. Reinforced quarry waste columns are also made in the same way as that of unreinforced columns except that horizontal strips are placed at desired position during tamping of quarry waste.

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Testing of column

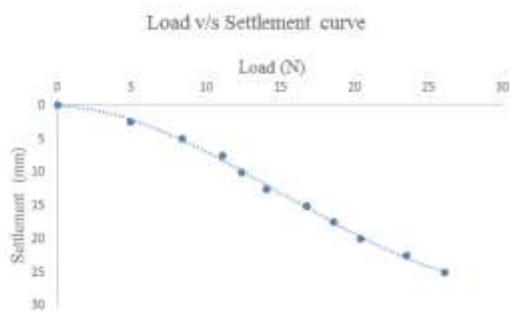
The reinforced clay bed is tested in Unconfined Compression Testing Machine under strain controlled compression loading at a settlement rate of 1.25 mm /min. The test is continued for a maximum settlement of 25 mm. Settlement is read out from a dial guage and total load applied is obtained from a proving ring of 20 kN capacity. At a given settlement, the applied vertical stress is found out by diving the total load by the area of the plate. A reference test is done on plane clay bed without any column. In case of reinforced column, at regular intervals geosynthetic reinforcements are provided as horizontal strips in the quarry waste column.

RESULTS AND DISCUSSION

Load Settlement Response with Inclusion of Lime Stabilised Quarry Waste Column

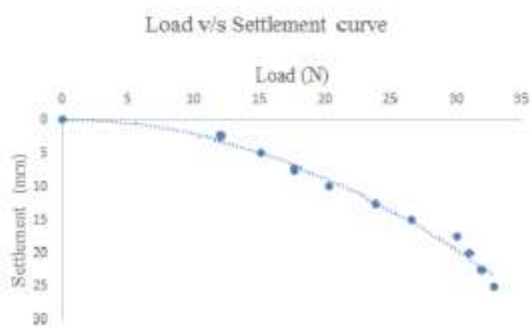
The results of the Unconfined Compression Tests are presented in the form of a graph plotted between load (X-axis) and settlement (Y-axis). Figure 3 presents the load settlement response of soft bed without column. Figure 4 shows the load settlement response of soft clay bed with quarry waste column. Figure 5 shows the load settlement response of soft soil bed with lime stabilised QW column. With the installation of lime stabilised QW column the load penetration curve shows a better load carrying capacity compared to soil bed alone and soil bed with QW column. Densification of the bed by stiffer quarry waste column and the cohesive property of the lime contributes to this improvement. The ultimate bearing capacity (obtained by dividing the load at 25 mm penetration by the area of footing) for soft soil bed without quarry waste column is 13.29 kPa, with quarry waste column is 16.71 kPa and with lime stabilised QW waste column is 27.31 kPa. Lime stabilised QW column inclusion increases the load carrying capacity by 105 %. To that of soil bed alone. Figure 6 shows the combined graph of soil bed alone, with QW column and also with lime stabilised QW column.

Figure 3:



Load Settlement response of soil bed alone

Figure 4:



Load Settlement response of soil with quarry waste column

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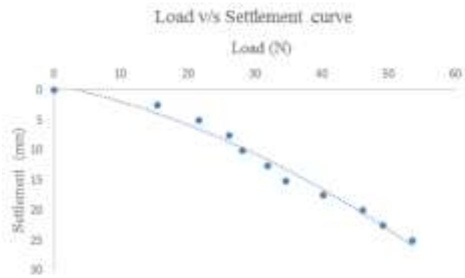
Figure 5:



Load Settlement curve for soil with lime stabilised QW column

Figure 6:

Load Settlement curve for soil bed without column, with quarry waste column and with lime stabilised QW column

Load Settlement Curve for Lime Stabilised QW Column Reinforced with Coir Geotextile at Different Spacing

Geotextiles are placed at various spacing to find the one which gives maximum efficiency. Various spacing selected are 75 mm, 50 mm, 37.5 mm and 25 mm. Figures 7, 8, 9, 10 shows the corresponding load settlement responses. H2M6 type of geotextile is used. The load carrying capacity increases by many folds, as the spacing of the reinforcement decreases. Mobilisation of the fictional stresses on the surface of the geotextile and the tension produced in the textiles by strike through of angular materials in the quarry waste into the geotextile opening resists the bulging of the column. Reinforcing the quarry waste column with coir geotextiles increases the load carrying capacity and it varies with respect to the L/S ratio.

Figure 7:

Load Settlement response for L/S ratio = 2.33

Figure 8:

Load Settlement response for L/S ratio = 3.5

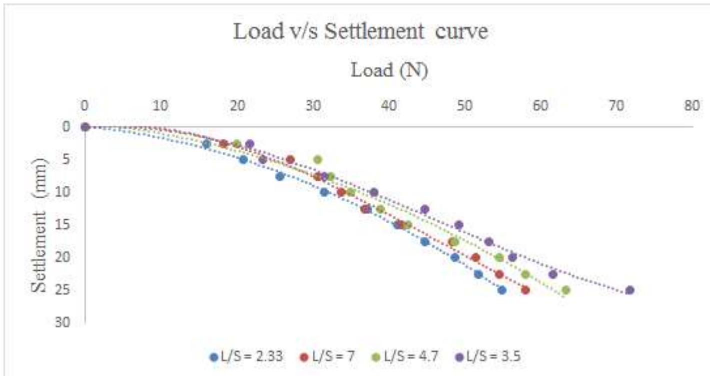
Figure 9:

Load Settlement response for L/S ratio =4.7

Figure 10:

Load Settlement response for L/S ratio = 7

Figure 11:



Load Settlement response for various L/S ratios

Maximum load carrying capacity is obtained for an L/S ratio of 3.5, i.e., for a spacing of 50 mm. For all other L/S ratios, i.e., 2.33 (75 mm); 4.7 (37.5 mm); 7 (25 mm) ,though the load carrying capacity is more than unreinforced, the difference is seen to be comparatively in a low margin among these L/S ratio. The load carrying capacity is lowest for an L/S ratio of 2.33. The load carrying capacities are found to be 28 kPa for a spacing = 75 mm, 36.6 kPa for a spacing of 50mm, 32.3 kPa for a spacing of 37.5 mm and 32.3 kPa for spacing of 25mm. The maximum load carrying capacity for an L/S ratio of 3.5 is found to be more than 33% and 175% when compared with unreinforced column and soil bed without column respectively. Hence it can be said that when the quarry waste column is reinforced with coir geotextile, maximum load carrying capacity can be obtained by maintaining a L/S ratio of 3.5, i.e., the spacing of 50 mm (2d).

CONCLUSION

The conclusions derived from the present study are listed below.

1. Inclusion of lime stabilised quarry waste column enhanced the load carrying capacity of soil by about 105%. This is because of densification of the soil by the quarry waste and due to the cohesive property of lime.
2. By lateral reinforcement of column using natural geotextiles, the load carrying capacity and stiffness can be increased. This increase is due to the mobilisation of frictional stresses on the surface of geotextiles.
3. For full depth reinforcement, coir geotextiles exhibits maximum load carrying capacity at a length to space ratio of 3.5 and a minimum load capacity at a length to space ratio of 2.33.
4. The maximum load carrying capacity for an L/S ratio of 3.5 is found to be more than 33% and 175% when compared with unreinforced column and soil bed without column respectively.

In general, reinforced quarry waste column may be considered as a cost effective and effective technique for improving the properties of soil. If this technique can be excellently used in practical application it will eliminate the problem of lack of good land for construction and also the expense of soil improvement

ACKNOWLEDGEMENTS

I express my heartfelt and sincere gratitude to GOD Almighty, for his choicest blessings for the successful completion of my seminar work without any hindrances.

I would like to express my sincere thanks to **Asst.Prof.C K Cherian ,** Head of the Department (i/c), Department of Civil Engineering, SAINTGITS College of Engineering, for his kind support throughout the completion of this venture With a greater respect, I express my sincere thanks to my coordinator **Asst. Prof. Hashifa Hassan P.,** Department of Civil Engineering, SAINTGITS College of Engineering, for the support and encouragement during the course of this work.

I am greatly debted to my guide **Er. Pavan Kumar C**, Asst. Professor, Department of Civil Engineering, SAINTGITS College of Engineering, for her valuable guidance and support that has been the source of inspiration throughout my seminar work. I expresss my sincere thanks to the staff-in charges of Geotechnical Engineering Laboratory.

I also express my Sincere thanks to my **Parents** and **Siblings** for their guidance and wholehearted support.

I convey my sincere thanks to all other **faculties** for their help and encouragement. I thank all my **friends** who have helped me during the work, with their inspiration and co-operation. Once again I convey my gratitude to all those persons who had directly or indirectly influenced on the work.

REFERENCES

[1] Guetif, Z., Bouassida, M. and Debats, J. M., "Improved soft clay characteristics due to stone column installation." *Computers and Geotechniques,* 34, pp. 104 -111. January 2007.
[2] Zahmatkesh, A., Choobbasti, A. J., "Settlement Evaluation of soft clay reinforced by stone column; considering the effect of soil." *IJRRAS*. vol.3, pp.159-166. November 2010.
[3] Ambily, A.P. and Gandhi, S. R., "Behaviour of stone column based on experimental and FEM analysis." Journal of *Geotechnical and Geoenvironmental Engineering,* 133, pp. 405-415. July 2007.
[4] Thornburn, S., "Building structures supported by stabilised ground." *Geotechniques,* 25, pp. 83-94.1975.
[5] Castro, J. T. and Sagastro, K. G., "Deformation and consolidation around encased stone column." *Geotextiles and geomembranes,* 29, pp. 268-276. April 2008.
[6] Wu, C. S. Hong., (2008). "The behaviour of laminated reinforced granular column." *Geotextiles and Geomembranes*, vol.26, pp.302-316.
[7] Deshpande, P. M., and Vyas, A. V., " Interactive encased stone column foundation." *6th International Conference and Exhibition on Piling and Deep Foundation,* DFI'96, ISSMFE, Bombay, ppl-19. December 1996.
[8] Issac, D. S., and Girish, M. S., "Suitability of different materials for stone column construction." *Electronic Journal of Geotechnical Engineering,* 14, pp. 268-276.December 2007
[9] Unnikrishnan, N., Rajagopal, K., "Behaviour of reinforced clay under monotonic and cyclic loading." *Geotextiles and Geomembranes,* vol.20, pp. 117-133. August 2002.