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REVIEW/RESEARCH ARTICLE/SHORT COMMUNICATION

Improvement of Loose Red soft soils using Aluminium foil encased stone columns

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Abstract

In this study, tests on embedded, floating single & group of stone columns with encasement of aluminium foil in loose red earth are conducted. Experiments are conducted on performance of single and group column arrangement and effect of encasement keeping the diameter constant.The model tests are carried out in a steel cylinder mould with a diameter of 250mm and a height of 150mm. The number of encased reinforcement(column)for embedding, as well as floating depths are studied in this study. Because of the requirement for serviceability in real foundation applications, outcomes of tests are assessed in terms of load improvement ratio at two settlement levels and settlement reduction factor, increments in load carrying capacity and reduction in settlement are investigated. It also investigates the reinforced red earth's load improvement ratio and settling reduction factor over loose soil. The behaviour of single and group columns, as well as the encasement influences on the improvement of loose red soil, are noticed.The test results revealed that addition of quarry dust columns can significantly improve the load carrying capacity of loose red earth while reducing settlement. In the laboratory stone column and encased stone columns response of load versus settlement are studied. The settlement in encased stone columns is lesser and the settlement decreased with the increasing stiffness of the encasing material.Our project's purpose is to offer less bearing capacity, limit total and differential settlements to accept the size of anticipated load, and provide long term satisfactory performance

KEYWORD: Red Soil , Reinforcement , Stone Column , Settlement, Bearing Capcity .

Introduction

Modification of the foundation soil or earth structures to improve performance under operating loading circumstances is known as ground improvement.These methods are increasingly being employed to make use of location with deteriorating design as well as subsurface condition and execution of the required project despite the presence of subsurface characteristics that would have previously rendered the project uneconomical or unfeasible.Vibro Replacement broadens the spectrum of soil which can be enhanced by vibratory methods. Ahmet Demirl et al (2013) explains, the model experiments on unreinforced and reinforced soft clay.With stone column strengthening , the load carrying capability of a soft clay foundation increases dramatically. The carrying capacity of the clay bed is improved, and settlement is reduced, thanks to the stone column. The stone column of smaller diameter has bearing capacity which is lower than the stone column of larger diameter [1].ChungsikYoo, A.M.ASCE (2010) studies on performance of encased geosynthetic stone columns on soft terrain for embankment building are presented in this research. Parametric analysis on controlling parameters like soft ground flexibility, length and rigidity of the geosynthetic encasement, and the embankment was carried out using a three-dimensional finite element model [2]. HamedNiroumand, et al.(2011) discovered that the ideal reinforcement arrangement for granular columns was ductile materials in plate form.The results showed that adding horizontal columns to granular columns increases their load carrying capacity, and hence their performances improves as the number of meshes grows [3]. S.Murugesan and K.Rajagopal investigate the findings of a set of model tests to explore the behaviour of encased geogrid columns are shown here. The effect of altering the encasement length, as well as the behaviour of isolated and group columns, were compared in tests [7]. Mohammed Y et al, (2010) discovered that as the undrained shear strength of the end carrying soil grows, the influence on the encasement length ratio increases with bearing improvement and settling reduction. To fully benefit from the end bearing soil support, the stone column's encasement should be stretched to its full length, specially for long columns with (L/d) more than 4 [9].Mereena K.P et al, (2009) explains about the unconsolidated undrained triaxial compression tests were performed on unsaturated clay samples, with and without central sand coir fibre core. The influence of the fibre content, relative core area, and confining stress on reinforcing clay samples were investigated using the data from triaxial compression test [10]. The result is clear that the deviator stress at failure of clay reinforced with quarry dust-coir fibre core increases with increase in fibre content up to 1% and then decreases.the optimum fibre content in the quarry dust-coir fibre core is 1%. Beyond this volume occupied by coir fibre in the quarry dust-coir fibre core increases, so as to develop fibre to fibre interaction than quarry dust to fibre interaction. As a result the frictional resistance developed in the quarry dust-coir fibre core decreases and the deviator stress at failure also decreases.The feed vibrators can be moist or dry which are driven inside the ground are used to accomplish this.Installation of a stone column as a load bearing member is to increase the resistance and compressive properties of sand, loose soil or heterogeneous fillings has been found as an effective ground improvement approach.When a project confronts severe foundation conditions, it requires improvement.The solutions are:

Particular sites are to be avoided.

Structure must be designed accordingly.

Modifying the existing ground.

A stiff structure must be designed which is not damaged by settlements.

The purpose of this study is to predict settlement behaviour of quarry dust column improved ground enwrapped in aluminium foil and also to compare the predicted settlement with the unreinforced or unimproved ground. For construction on soft soil, the use of stone columns are cost effective and is a technology for ground improvement that is viable. The stone columns not only operate as reinforcing material, enhancing the compressible soft soil's overall strength and stiffness, but they also promote consolidation through proper drainage. The basic idea behind a stone column is to replace the loose material with compacted stone, as well as densify and reduce the compressible nature of the earth, which creates a composite material. Because the stone columns bend under weight, their capacity is determined by degree of stiffening achieved in the surrounding and internal friction between the columns.The following are the most prevalent methods for construction and the typical site conditions where they are used :

1. Vibro Replacement: It is done by launching the probe to the necessary depth, a hole is created in the ground.When borehole stability is in doubt, the wet method is typically used. As a result, it is best suited to places with soft to hard soils and a high groundwater table.

2.Vibro Displacement:This is a dry technique that is called vibro displacement. The fundamental feature between vibro displacement and vibro replacement is that the former does not require the use of water during the initial development of the hole. To employ this procedure, the vibrated hole should remain open even after the probe is removed.The properties of geopolymer concrete were studied by several researchers (Xie et al., 2019; Li et al., 2019; Jena and Panjgrahi, 2029; Amran et al., 2020; Noushini et al., 2020; Shahmansouri et al, 2020; Amran et al., 2021; Moghaddam et al., 2021; Shahmansouri et al., 2021). The source materials and alkaline liquid are fundamental parts of geopolymers. A complete survey about these constituents and whatever other admixtures that may have constructive outcome on the conduct of Geopolymers will be introduced by writings, use of sodium silicate to sodium hydroxide as the alkaline liquid upgraded the reaction between the source material and the alkaline liquid. Hence, starting blend plans for the creation of geopolymer substantial utilizing sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) to frame the basic arrangement were ready. Cost of Potassium based arrangement was another factor that impacts the dynamic of utilizing alkaline liquid. A path and blunder measure utilized for calibrating the strength of the blends, including diverse base debris substance. Creation of geopolymer concrete were continued with Testing techniques and standards for manufacturing of OPC concrete. It could assist with an applicable correlation between the two items. source proportion as a significant factor in mechanical properties of concrete was fixed at 70% by weight inside the blend and its size, dampness content, shape and fineness modulus were noticed cautiously to explore the impact of replace of fly ash and aggregates were utilized distinctly from one source.

Materials and Methods

Loose red earth

The soil sample is taken from the natural ground level at one meter depth via open excavation. After oven drying and filtering through 4.75mm sieve, the properties are shown in table1 and loose red earth is shown in Figure 1.

Figure 1: loose red earth.

Table 1: Properties of loose red earth

Properties	Value
Water content	6.88%
Relative density	2.62%
Liquid Limit	34.2%
Plastic Limit	23.22%

Limit of shrinkage	16.92%
Optimum Moisture Content	12%
Max Dry density	1.79g/cc
Uniformity coefficient	7.64
Curvature coefficient	0.87

Quarry dust

Quarry dust is sieved till the fine aggregates produced are similar to that of sand fine aggregates. The quarry dust fine aggregates range from 2.36mm to 150um.The properties are shown in Table2. Figure 2 showcases the waste quarry dust.

Figure 2: waste quarry dust

Table 2:Quarry dust properties

Properties	Value
Relative Density	2.53%
Uniformity coefficient	5.33
Curvature coefficient	1.47

Mild steel bar

Mild steel round bars of 8mm dia are used for fabrication of 15cm, 10cm, and 5cm length columns. Fabricated steel columns are shown in Figure 3.

Figure 3: Fabricated columns

Aluminium foil

It is used as an enclosure which is a solid sheet . The most important characteristic is its permeability to water vapour and gases. Figure 4 shows fabricated columns encased with aluminium foil to form the requisite size of the column and figure 5 shows loading cell setup

Figure 4: fabricated columns encased with aluminium foil to form the requisite size of column.

Figure 5:loading cell setup.

Methodology

1)Varying lengths of encased stone columns are subjected to numerous D/B ratios, 'D' signifies the test tank diameter and 'B' refers to the diameter of circular model footing. These are the numbers 1, 2, and 3 that were observed for an 8mm stone column, respectively.2)The footing test is carried out for different number and spacing of the columns for embedded depth, floating depth, and intermediate depth, such as 5cm, 10cm, and 15cm.3) Model footing tests are used to investigate the load setting properties of loose red soil using stone dust column coated in aluminium foil. 4) Conclusions are given based on the experimental findings.

Preparation of loose red earth deposit:

To eliminate any friction between soil and tank wall, oil is applied to the tank wall. To maintain a density of 1.41g/cc, the quantity of required soil is combined with 2% water content and properly mixed dirt is placed in the tank in three layers using the rainfall approach. In the test bed, great care was taken to make sure no large airgaps are present.

Construction of stone column:

The column can be built wet or dry. For single and group arrangement patterns, enwrapped mild steel single and group columns of the required length wrapped with aluminium foil are put in the centre of the tank's bottom. Fabricated columns raised in stages without disturbing the surrounding soil. The total weight of the quarry dust poured into the column is calculated for the densities of 1.85g/cc,1.98g/cc and 1.59g/cc.

Spacing of stone column:

According to IS regulations, the space between the columns should be (1.5 to 3)d, 'd' represents stone column diameter . The four numbers columns are spaced 3d c/c along the perimeter, while the five numbers columns are spaced 1.5d c/c along the periphery and centre. Figure 6 and 7 shows spacing encased columns and typical test arrangement respectively.

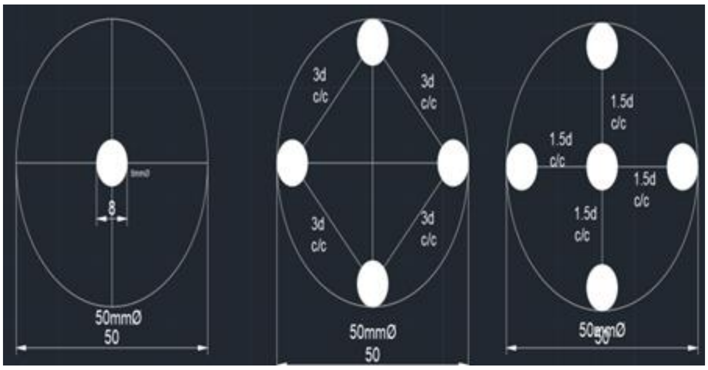


Figure 6: spacing of encased columns.

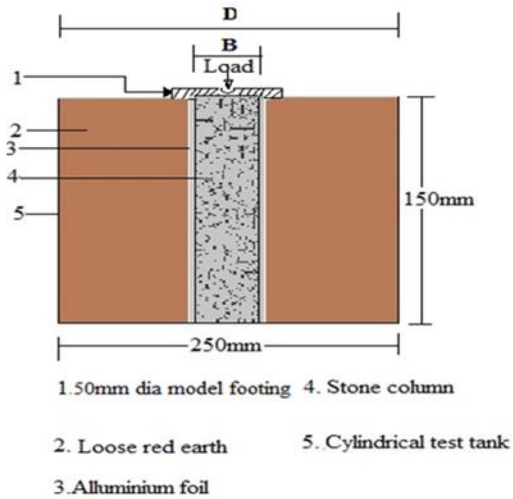


Figure 7:shows a typical test arrangement

Procedure:

Step 1: The model test tank is a circular steel tank with diameter of 250mm and a height of 150mm. To lessen the boundary effects, the side walls of the tank were coated with a lubricating gel.

Step 2: Fabricated column of 8mm dia of 15cm length of single no which is enwrapped with aluminium foil is placed at the centre point, marked in the test tank.

Step 3: The needed soil sample weight is determined for least density of 1.41 g/cc, which is obtained as a result of compaction test and well mixed with 2% water and put into the test tank in three layers using the rainfall techniques. The blank spaces in the sample are tamped out using a tamping rod.

Step 4: To maintain the density of the column at the centre, samples of soil are fed to the testing tank.

Step 5: The fabricated column is raised carefully without the foil from the test tank.

Step 6: In the test tank, a hollow column wrapped in foil is constructed.

Step 7: Quarry dust is poured into a hollow column with length of 5, 10, 15cm which is reinforced with a paper cone.

Step 8: The 50mm diameter circular model footing is precisely set on top of the stone column.

Step 9: To avoid eccentric loading, the footing was perfectly aligned with the loading jack's centre.Then load transferred to footing is measured using a calibrated proving ring. Small increments of load were delivered at a constant rate of strain. Each load increment is maintained at the same level until the footing settles. Deformations are measured using three dial gauges mounted on the footing.

Step 10: For 20mm and 30mm of settlement, the ratio of load improvement and factor of settlement reduction are determined.

Results

Test results of model footing:

The encased stone column's load deformation behaviour is investigated by putting in a triaxial loading frame at a strain rate of 1.22mm/minute. Load-settlement properties of soil is depicted after a model footing test is performed on the red earth that has been compacted to a lower density without compacting. Upto a 30mm average deformation, settlement is observed for equal interval of load. Load versus settlement graph for unreinforced soil is shown in figure 8.

Figure 8: load versus settlement graph for unreinforced soil.

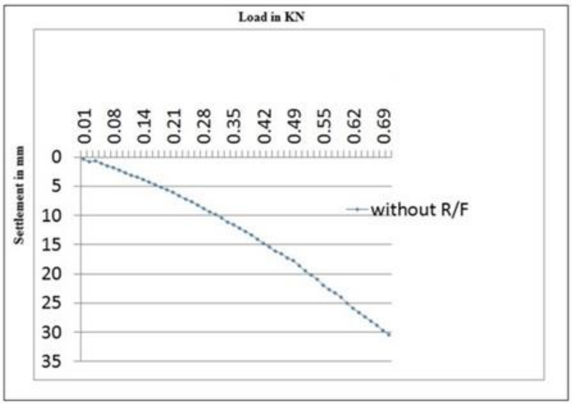
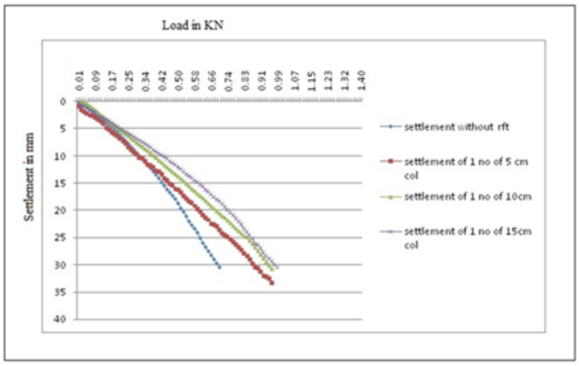


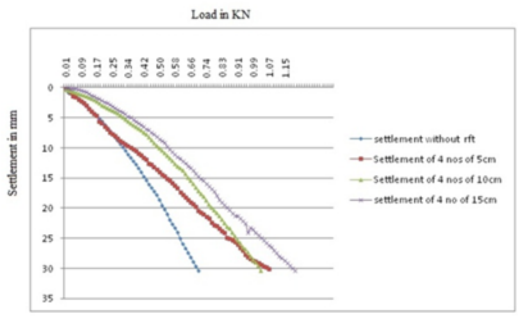
Figure 9: load versus settlement graph for single column of encased quarry dust column.

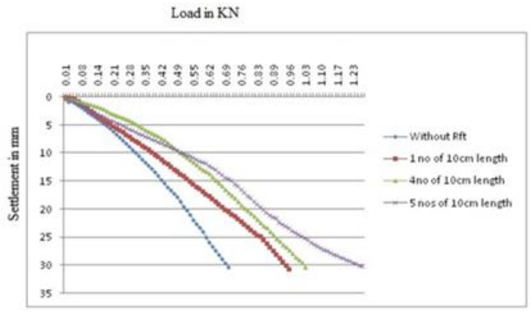


Load-settlement characteristics of soil are plotted in the above graph.The above graph demonstrates that the soil settles at lower places, 0.53 KN at 20mm, which is not significant and hence it requires reinforcement. Load versus settlement graph for single column of encased quarry dust column is shown in figure 9. The graph is obtained by conducting a model footing test for single columns of 5cm, 10cm, and 15cm with encased aluminiumfoil.Load improvement ratio varies linearly with settlement.

Figure 10: load versus settlement graph for group of 4 No. of columns.

Figure 11: load -settlement for encased 10cm length column.





Load versus settlement graph for a group of 4No. Of columns is shown in the figure 10. The following can be stated from the above graph:

1.The weight increase for four 5cm,10cm and 15cm quarry dust columns compared to loose red soil with respect to 30mm settlement is 51.42percent, 46.71percent and 71percent respectively.

Analysis of load settlement for various patterns for encased quarry dust columns Load -settlement for encased 10cm length column is shown in the figure 11. The graph represents the model footing results for 10cm length columns arranged in single and group patterns. There is marginal fluctuation between four and five number columns, and in the beginning of the loading, the five number columns settle faster than four number columns upto a settlement of 10mm.

Load analysis of single and group encased columns

The ratio of reinforced to unreinforced load is referred to as load improvement ratio. It is given by the equation,

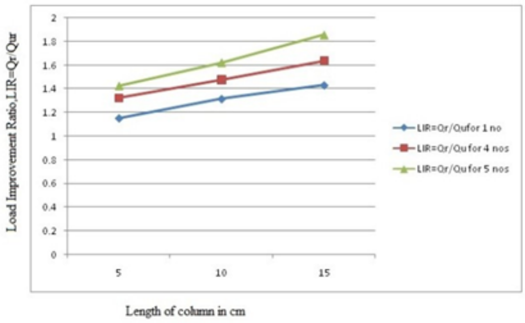
LIR=qu/qur

Table 3: Load improvement ratio increases with respect to length of columns corresponding to 20mm settlement . Load Improvement Ratio = qr/qur for length of columns at 20mm settlement

Length in cm	LIR=qr/qur for 1 No	LIR=qr/qur for 4 No.s	LIR=qr/qur for 5 No.s
5	1.152	1.326	1.427
10	1.315	1.479	1.623
15	1.431	1.636	1.855

The following table shows the load improvement ratio as a function of the length of the enclosed quarry dust column. The results are plotted in the graph shown in the figure 12

Figure 12: load improvement ratio corresponding to 20mm settlement



The force applied to the columns varies linearly with column length, resulting in an increase in load carrying capability as the length of the encased quarry dust columns increases. As a result, the length and number of the quarry of enclosed quarry dust columns increases, the load carrying capacity also increases. The settlement analysis of single and group encased columns

The settling conditions should be met by a competent foundation system. A week ground treated with quarry dust column will settle less than an untreated ground, so investigators developed the phrase “settlement reduction factor”to describe the settling criteria.Settlement reduction factor is determined by the relation

$$\beta = (SO-Sr)/So$$

Table 4: With respect to the length of the columns, the percentage increase in the settlement reduction factor is equivalent to 20mm settlement. Settlement Reduction Factor, SRF=(So-Sr)/So)for length of columns at 20mm settlement.

Length in cm	SRF=So-Sr/So for 1 No.	SRF=So-Sr/So for 4 No.s	SRF=So-Sr/So for 5 No.s
5	0.144	0.267	0.308
10	0.282	0.464	0.487
15	0.364	0.546	0.442

Settlement analysis for columns of different length and different No's. is represented in the above table. A graph depicting the fluctuation of the settlement reduction factor with length and number of columns is plotted using the above table results. The settlement reduction factor for 5 No. 15cm columns falls when compared to 5 No. 10cm columns, resulting in a settlement of 20mm.

Table 5:For single and multiple enclosed columns, the settlement reduction factor Increase in settlement reduction factor by a percentage across the length of the column upto a 20mm settlement

Length in cm	SRF for 1 No	SRF for 4 Nos	SRF for 5 Nos
5	95.83	73.78	58.11
10	29.07	17.67	-9.24
15	152.77	104.49	43.50

Over the length of the column, there is a significant increase in the settlement reduction factor, equating to 20mm settlement. According to the findings, a 15cm long encased quarry dust column is noticeable when compared to 10cm and 5cm long encased columns reported at 20mm settlement.

Table 6 : Percentage increment of Settlement reduction factor over length of column at 30mm settlement

Length in cm	**SRF for 1 no**	**SRF for 4 nos**	**SRF for 5 nos**
5	51.80	32.42	38.44
10	17.21	18.07	-97.08
15	77.92	56.36	37.04

Over the length of the column, the percentage increment of the settlement reduction factor equal to a 30mm settlement, According to the findings, a 15cm long encased quarry dust column is noticeable when compared to 10cm and 5cm long encased columns reported at 30mm settlement.

Conclusıons

The conclusion drawn are:

The findings show that the encased aluminium foil increases the rigidity of the quarry dust column and decreases the weight transferred to the soft surface, lowering total settlements. It demonstrates that full encased aluminium foil shows a stronger impact in circumstances when settlement minimization is the primary goal.

Quarry dust is a waste material which is produced at construction sites in abundance and is proved to be economically, technically feasible to use as reinforcement for stone columns.

At 20mm and 30mm settlement, when the length of column is considered, there is a marginal load improvement ratio corresponding to 15cm length of the encased column. Hence embedded depth of column with encasement is beneficial compared to 10cm and 5 cm encased quarry dust columns.

At 20mm settlement and 30mm settlement, when the No. of columns are considered, we can observe marginal improvement in load ratio increment, Five No.s columns arranged along periphery and centre is beneficed combination compared to one No.and four No.s encased quarry dust columns.

At 20mm and 30 mm settlement , when the length of encased quarry dust columns are considered where substantial increment is observed hence 15 cm embedded column with full encasement is proved to be highly beneficial.

Five No.s columns arranged along periphery and centre is proved to be a beneficial combination for appreciable reduction of settlement.

Embedded depth of columns with full encasement is proved to be beneficial to provide when settlement factor and load improvement are considered to be main criteria.

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