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Performance Assessment of Treated Jute Fiber Encased Stone Columns in Improving Soft Clay Beds

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Abstract. Stabilization of soils becomes an important concern in preparing the soils before construction of structures. Especially in soft clayey soils or soils near to coastal region i.e., soft marine clays, the ground improvement becomes essential so that there is an improvement in bearing capacity and reduction of settlement due to the applied loads. This paper presents the results of experimental tests done on laboratory scale model of a sample of compressible soil specimens reinforced with conventional stone columns, treated jute fiber encased stone columns and comparison is done with these with reference to soils without any stone columns. The core objective is to evaluate the bearing capacity and settlement behavior of the soils which are reinforced with conventional stone columns, treated jute fiber encased stone columns. The experimental results have been compared with existing statistics proposed in the literature. The specimen consists of soft clayey beds that are reinforced with stone columns prepared with HBG (*Hard Broken Granite*) metal with sizes between 2 to 6.3 mm. The results show that the increment in bearing capacity and decrement in settlement of soil is found out when the soil is reinforced with the stone column encased with treated jute fabric.

Keywords: Bearing capacity, Compressible soils, Encased Stone Columns, Settlement, Soft Clays

1 Introduction

The various potential problems that are associated with certain problematic soil deposlits such as peat, soft clay, marine clay etc are safe beaaring capacity, higher compressibility, lateral flow tendency etc., Such soil beds require proper treatment methods for the increment in the engineering behaviour on par with the design requirements of the structure. One such method is utilization of stone columns for these problamatic soils. Stone columns or granular piles are the vertical column elements which are formed beneath the ground level by compaction of uncementitious stone fragments or gravels. When the stone column is subjected with vertical loading, it undergoes compression vertically because of the aggregate bulging. With the bulging of column, it moves downward and the granular material compresses the soft soil and transmits the stress to the soil by means of shear. Such bulge causes the increment in lateral stress within the clay that provides extra confinement for the stone. Geosynthesized encased stone columns are very efficient in enhancing the soft clay under moving vehicles cyclic loading [1]. The behaviour and performance of the stone columns can be enhnaced by adding the plastic fibers with sand and smaller amounts of gravel [2]. The impact of geogrid encased stone columns are studied and reported that extra lateral confinment is generated because of the column encasement which leads to enhnaced load carrying capacity [3]. Such drawbacks can be mitigated by wrapping every stone column with a jute fiber matrix. The jute fiber encasement enables in easy formation of the stone column and enhances the stiffness and strength of the columns. Various advantages can be achieved from the encasement of stone columns such as stiff column which prevents the stones loss into the adjacent soft clay etc., [4-9]. The major limitation of this technique is that it completely depends on the adjacent clayey soils for the purpose of moblization of load bearing capacity. The load capacity may not be enhanced more than 25 times the strength of soft clay [10]. A state of equilibrium is reached eventually which results in decrease in vertical movement on par with unimproved soil [11]. Apart from this, in soft clays, the installation of stone columns might be tedious with stone losses because of the low confinement from the adjacent soft clays and the contamination of stone aggregate by the inclusion of soft clay soil may decrease the frictional strength of the aggregate and impede the function of drainage within the column [12]. The composite system i.e., Coir Geotextile-Encased Stone Columns with Tyre Crumb-Infilled Basal Coir Geocell can substantially enhances the load-settlement response of soft soils by inhibiting greater extent of equal load settlement profiles[13]. The impact of the geometrical dimensions and other related parameters on the behavior of stress vs strain of encased and uncased stone columns significantly influences the bearing capacity of soft soils by reducing the total and differential settlements as per given circumstances[14]. The treated stone columns results in an enhnacement in settlement improvement ratio when blended with crushed stone, cement, dry lime in various proportions and the increment is in the range of 5.5-13.5 kPa and also there is a drop in settlements in the range of 77-91% when compared with untreated stone columns [15].

It has been reported by many researchers, that the increase in bearing capacity and decrease in settlements of soft clays can be achieved by stone columns techniques. In the present work an attempt is made to study the load settlement behaviour of soft clay beds with and without treated jute fiber encased stone columns as reinforcement. Conventional stone columns and Jute fiber encased stone columns at center of the model box were studied to assess the load settlement behaviour of soft clay beds. The effect of jute fiber encasement and gradation of the metal (6.3mm - 2.0mm) were also investigated. The novelty of the current study reveals the compound effect of confinement through encasement concomitantly the influence of the gradation of the fill material.

2. Materials

Details of various materials used during the experimentation are reported below.

2.1 Soil

The soil used in this study was marine clay collected from ‘Kakinada Seaport Limited (KSPL), Kakinada’, East Godavari District, Andhra Pradesh State, India. Inorganic clay of high compressibility (CH) is the categorized soil as per IS division. The properties of the marine clay assessed based on relevant I.S. Code provisions, are given in Table 1

S.No	Property	Value
1	Specific Gravity	2.60
2	**Grain size Distribution**	
	Sand (%)	9
	Silt (%)	20
	Clay (%)	71
3	**Compaction Properties**	
	Maximum Dry Density (kN/m^3)	13.8
	OMC (%)	27.2
4	**Atterberg Limits**	
	Liquid Limit (%)	78
	Plastic Limit (%)	33
	Plasticity Index (%)	45
	Shrinkage Limit (%)	14.8
	IS Classification	CH
5	Differential Free Swell (%)	42
6	Safe Bearing Capacity(kPa)	32.86
Shear parameters		
7	C (kPa)	30
8	Ø (Degrees)	0

2.2 Metal

HBG (Hard Broken Granite) metal with sizes between 2 to 6.3 mm was used as reiforcing material for preparing stone columns.

2.3 Jute fiber

Jute fiber was procured from local market and is treated and used as encasing material for columns.

2.4 Preparation of Stone Column

Stone columns of size 5 cm in diameter and 50 cm height was prepared with Granular material (from 2 mm to 6.3 mm at different combinations) .These columns are installed in soft clay beds which were already prepared in the model tank(Joel Gniel and Abdelmalek Bouazza 2009)[3].

3. Experimental Study

A model box of dimensions 50 cm (L) x 50 cm (B) x 60 cm (H) is fabricated by using 8 mm thick transparant plates. Clay bed was prepared in the model box in layers each of 5 cm to its OMC and MDD up to full height of the model box.

3.1 Model Tests

Tests were carried out by installing the un encased and treated jute fibre encased stone columns at center in Model box by adopting the standard procedures in the laboratory.

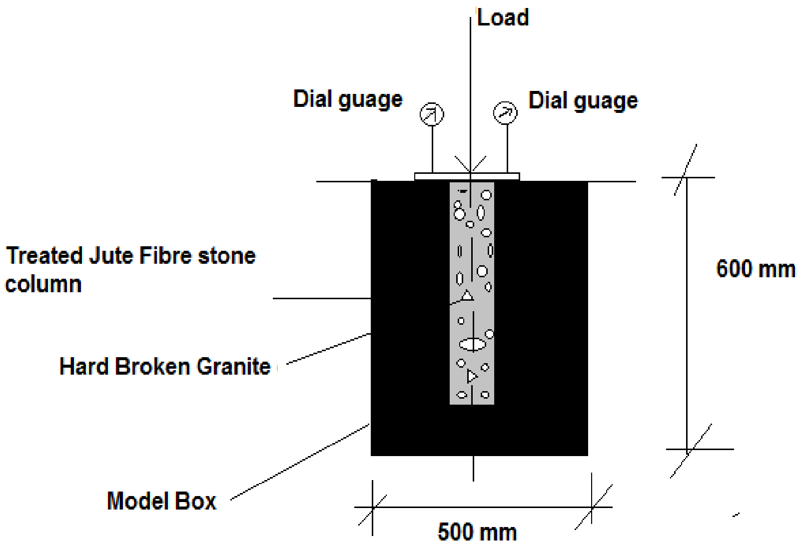

Fig.1.0 Schematic Diagram of Modal Load Test set up

Model No.	**Description of the Model**
Model - I	Unreinforced soil model
Model - II	Reinforced without encasement (4.75mm passing and 2mm retained metal)
Model - III	Reinforced without encasement (6.3mm passing and 4.75mm retained metal)
Model - IV	Reinforced without encasement (6.3mm passing and 2mm retained)
Model - V	Reinforced with treated jute fiber encasement (4.75mm passing and 2mm retained metal)
Model - VI	Reinforced with treated jute fiber encasement (6.3mm passing and 4.75mm retained metal)
Model - VII	Reinforced with treated jute fiber encasement (6.3mm passing and 2mm retained metal)

All the prepared Models (Model 1 to Model 7) are mounted on the testing machine, a bearing plate of size 10cm x 10cm x 0.5 cm is placed centrally at the top of the box. Load is applied gradually at a rate of 10 N/s and the corresponding settlements were recorded by attaching two dail gauges at the top of the bearing plate.Load tests were conducted on unreinforced and reinforced soil model in the laboratory.

Fig 2.0. Model box with soft clay bed installed with treated jute fibre encased stone columns.

4.0 Results and Discussions

The results obtained from laboratory experimentation were tabulated and are discussed below.

Model No	Ultimate Load (N)	Settlement (mm)	Safe Bearing Capacity (kPa)
Model-1	493.66	28	32.86
Model -2	1840	21	122.66
Model -3	2031.12	19	135.4
Model -4	2274.3	17	151.6
Model -5	2632.14	14	175.46
Model -6	2860	11	190.66
Model -7	3195.36	08	213

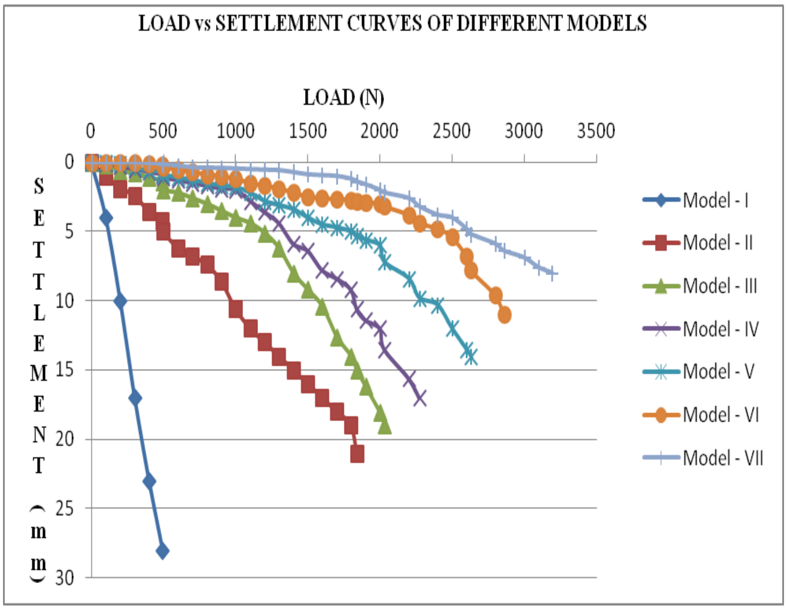

Fig 3 .0 Load vs Settlement curves of reinforced and unreinforced models

The above fig.3.0 shows the load-settlement curves for different soil models (Model:1-7) constructed with and without reinforcement.

From fig.3.0 the load carrying capacity has substantially increased for Models 2-7. The improvement in load carrying capacity and the decrease in settlement could be attributed due to the installation of unencased and encased stone columns.

The ultimate load carrying capacity is enhanced by 2.73, 3.11, 3.61, 4.33, 4.80 and 5.47 times for the Models 2-7 with respect to unreinforced soil model(Model-I). The settlements are decreased by 25%,32%,39%,50%,61% and 72% for the Models 2-7 with respect to unreinforced soil model(Model-I).

The increase in load bearing capacity and decrease in settlements is due to the mobilizaion of lateral confinement in the models. It can be observed from the test results, that the load carrying capactiy of treated jute fiber encased columns is further enhanced due to encasement of stone columns i.e., for Models:5-7. This encasement imparts lateral confinement to the stone columns and also makes the stone column to act as load bearing elements.

The load carrying capacity of unencased columns was observed less when compared to the treated jute fiber encased columns. However, the load carrying capacity of both unencased and treated jute fiber encased columns is enhanced when compared to the Model-I (without reinforcement).

5. Conclusions

1. The load carrying capacity of unencased reinforcement Models i.e., II-IV is enhanced when compared with unreinforced model i.e, Model –I and the increment is in the range of 2.73-3.61 times respectively.
2. The settlement of unencased reinforcement Models i.e., II-IV is decreased when compared with unreinforced model i.e, Model –I and the decrement is in the range of 25-39% respectively.
3. The load carrying capacity of encased reinforcement Models i.e., V-VII is enhanced when compared with unreinforced model i.e, Model –I and the increment is in the range of 4.33-5.47 times respectively
4. The settlement of encased reinforcement Models i.e., V-VII is decreased when compared with unreinforced model i.e, Model –I and the decrement is in the range of 50-72% respectively.

Based on the laboratory model studies and the test results data, it can be concluded that the soft clay beds can be strengthened and the settlements can be decreased more efficiently by the technique of treated jute fiber encased stone columns.

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