Laboratory Model Tests on Tyre Chips-Aggregate Columns

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Abstract— The stone column technique is a very efficient method of improving the strength parameters of soil like bearing capacity and reducing consolidation settlement. It offers a much economical and sustainable alternative to piling and deep foundation solutions. Ground improvement when implemented through stone column technique aids in a much stable solution to construction in weak cohesive soils. Considering the cost aspect of stone column, the major portion owes to the cost of stone aggregates. Stone aggregates are scarce, natural resource and it is diminishing. Hence it is advisable to use some other cheaper material which can replace the stones without affecting the performance of stone column. This paper involves the study of load - settlement response of stone columns in which aggregates are partially replaced by shredded tyre chips. The variation in load carrying capacity of stone columns with different mix proportion of aggregates and shredded tyre chips are also determined. The results indicate that waste tyre chips can be effectively used as partial replacement of stone aggregates.

Key words: Stone Column, Load Carrying Capacity, Tyre Chips, Ground Improvement

I. INTRODUCTION

Stone column is a technique in which a part of the soft soil is replaced with harder materials such as stones. Stone columns are extensively used in soft cohesive soils to improve bearing capacity of poor ground, stiffness of poor ground, shear strength of soil and to reduce the settlement of structure and liquefaction potential of soft ground. Stone columns also act as vertical drains thus induce rapid consolidation process. Moreover, compaction of granular materials during the installation processes and replacing the soft soils with stronger materials significantly increase the unit weight of the soil. A stone column develops its vertical load carrying capacity by the lateral pressure provided by the surrounding soil. Increasing demand in conventional materials like stones, aggregates, sand etc. requires the use of cost effective materials for soil stabilizing techniques. The stone column technique is widely used to strengthen the ground to support embankment, oil tanks on poor ground, low-rise buildings, highway facilities, bridge abutments, air field applications etc. So it is necessary to find out a cost effective and environmental friendly technique. But now the studies are going on to replace this costly material by alternate materials such as quarry dust, silica manganese slag etc. These materials are not only cost effective but also important in the point of view of environment.

Use of waste materials will help to preserve nature and will provide a greater economy. [1]

Tyre disposal remains a problematic issue in industrialized nations around the world. Waste tyres have many properties which result in their being of value from a civil or geotechnical engineering perspective: low density, high strength, hydrophobic nature, low thermal conductivity, durability, resilience and high frictional strength. Thus Scrap tyres are valuable and viable national resource; the challenge today is to find the best way to utilise them in a wide range of applications. In this paper, an attempt has been made to study the performance of mixture of shredded tyre chips and conventional stone aggregate as column material for the improvement of clay.[3]

II. PREVIOUS STUDIES

Tandel Y.K et al., (2012) conducted the experiment to compare the performances of an ordinary stone column and reinforced stone column. By reinforcement using geosynthetic ,sand columns are confined and the lateral bulging is minimized and the load capacity of the sand column can be increased and they also found that elastic modulus of the geosynthetic reinforcement plays an important role in enhancing the load carrying capacity of reinforced column due to the confining pressures.

Murugesan et al. (2010) studied the behaviour of single and group of geosynthetic reinforced stone column and found that there is clear improvement in the load capacity of the stone column due to encasement. The increase in the axial load capacity depends very much upon the modulus of the encasement and the diameter of the stone column due to the confining stresses generated. Encased stone columns will behave as semi rigid piles due to the increase in stress concentration with increase in modulus of encasement.

Balan et al. (2013) studied the behaviour of geosynthetic encased quarry waste column. The results obtained are Inclusion of quarry waste column increases the load carrying capacity of the soil. Stiffness of the stone column can be increased by lateral reinforcement of column using natural geotextile. The improvement in load carrying capacity of reinforced column also depends on embedment depth.

Ayothiraman et al. (2009) conducted an experimental study using shredded tyre chips as stone column material. They found that mix proportion of 20%Tyre chips+80%Stone aggregates shows high load carrying capacity than stone column with only stone aggregates. Combination of stone aggregates and tyre chips would give much higher load carrying capacity of stone columns due to higher interlocking of stone aggregates and tyre chips. Both materials are having same plastic deformation. This means that deformed or bulged stone columns does not regain its original shape during unloading even if tyre chips are used.

Gowri et al. (2015) conducted the experiment using silica manganese slag as stone column material with lateral reinforcement. They found that settlements are decreased when geotextile is used. Improvement in load carrying capacity of reinforced column also depends on the reinforcement depth. Maximum bulging has been found at half of the length of stone column for unreinforced column and for all reinforced columns, bulging is found just below the reinforcement depth.

Shailesh et al. (2007) had done a detailed experimental study on behavior of single column and group of seven columns is carried out by varying parameters like spacing between the columns, shear strength of soft clay, and loading condition. Experiments are carried out by loading the column area alone as well as the entire unit cell area to study the limiting axial stress on the stone column and stiffness of improved ground, respectively. When column area alone is loaded, failure is by bulging with maximum bulging at a depth of about 0.5 times the diameter of stone column. As spacing increases, axial capacity of the column decreases and settlement increases up to spacing -to-diameter ratios of 3 , beyond which the change is negligible.

Ashraf et al. (2013) give a systematic verification of the effectiveness of different types of materials used for stone column. They found out that the inclusions of stone columns improve the load deformation characteristics of clay. Stones are found to be most effective material for the stone column. Quarry dust can be effectively used for the stone column construction. They found out that river sand is more effective than sea sand. Effectiveness of the stone column increases as the spacing between the stone columns decreases. They also concluded that the load settlement response from the numerical analysis is found matching with the experimental results.

III. MATERIALS AND METHODOLOGY

The soil samples used for the study was collected from Althat, Thrissur District, Kerala. Stone aggregates were collected from the local quarry and tyre chips collected from tyre shredding unit, KINFRA Rubber park, Irapuram. The sand used is clean river sand collected from Manathala in Thrissur district. Sand used as a blanket is sieved through 4.75mm IS sieve and is classified as well graded sand with specific gravity of 2.66. Here shredded tyre chips and aggregates were used as stone column material and plate load tests were carried out to determine the load settlement behaviour of the stone columns prepared in a tank.

The plate load test was conducted for single column, group of columns using stone alone, 90%Stones(S)+10%Tyrechips(T), 80%S+20%T, 70%S+30%T, 60%S+40%T, 50%S+50%T and for clay bed alone.

The spacing between the columns is kept constant as 2.5 times the diameter of the column.

A. *Materials used*

Index properties of soil and aggregates were tested in accordance with IS codes and the results are presented in Table 1 and Table 2 respectively. Tyre chips of size 5mm to 10 mm and stone aggregates of representative size 5mm to 10 mm is used for the study.

Properties		Value
Natural water content (%)		21
Specific gravity		2.52
Particle size distribution	Percentage Gravel(%)	0.4
	Percentage Sand (%)	27
	Percentage Clay (%)	39.4
	Percentage Silt (%)	33.2
Liquid limit (%)		51
Plastic limit (%)		23
Shrinkage limit (%)		16
Plasticity index (%)		28
Soil classification		CH
Maximum Dry density (kN/m^3)		18
OMC (%)		19
Unconfined Compressive Strength(kN/m^2)		67.6
Free swell (%)		7

Table 1: Index Properties of Soil

Properties	Value
Specific gravity	2.6
Density (kN/m^3)	15.7
Effective particle size, D10 (mm)	7

Table 2: Properties of Aggregates

B. *Preparation of Clay Bed*

In order to study the load settlement behaviour of stone columns plate load test were conducted. The clay bed for the tests was prepared in a test tank of plan dimensions 500mm X 500mm and 600mm in depth. This tank was filled with soil sample at maximum dry density. It was filled in layers to the desired thickness by hand compaction such that no air voids are left in the soil. The compacted soil is left for 24 hours and covered with wet gunny cloth for moisture equalization. For each load test, a fresh clay bed was prepared in the test tank and stone columns of 25mm diameter and 550 mm height were installed in it.

C. *Installation of Column*

Fig. 1 shows the arrangement of the stone columns for laboratory model tests. The spacing between the columns is kept constant as 2.5 times the diameter of the column.

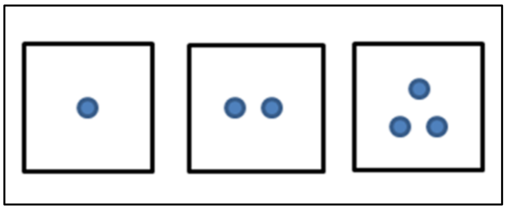

Fig. 1: Arrangement of Stone Columns

IV. RESULTS AND DISCUSSIONS

The load settlement characteristics of single and group of columns are discussed in the following sections. It was seen that the load carrying capacity of soil before the installation of stone column was 44kN/m^2.

A. *Load –Settlement Characteristics of Single Column*

From Fig.2 we can see that load carrying capacity increases with the replacement of aggregates by tyre chips. This is because of the higher interlocking of the tyre chips and stones. [3].The results obtained shows a similar trend to the previous study conducted by R. Ayothiraman and S. Soumya (2011) using shredded tyre chips partially replacing stone aggregates in stone column.

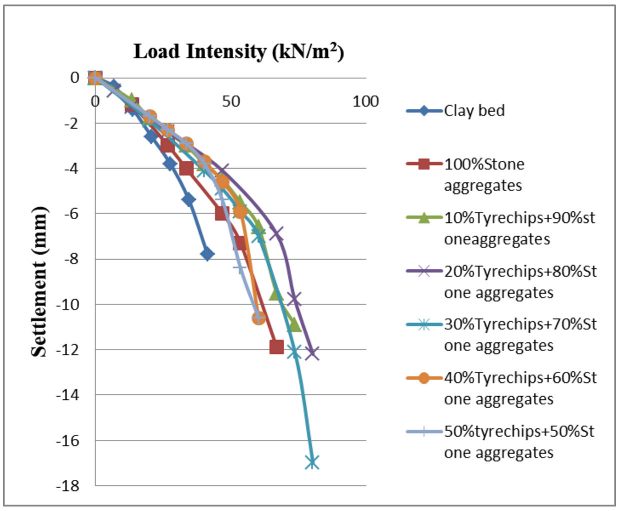

Fig. 2: Load settlement Graph of Single Column

B. Load –Settlement Characteristics of Two Columns

Fig.3 compares the load settlement curve for two columns of tyre chips-aggregates columns. Combination of stone aggregates and tyre chips would give much higher load carrying capacity of stone columns due to higher interlocking of stone aggregates and tyre chips.[3]

According to the study conducted by Murugesan and Rajagopal (2010) on the behavior of single and group of ordinary stone columns, the load carying capacity increased with number of columns.

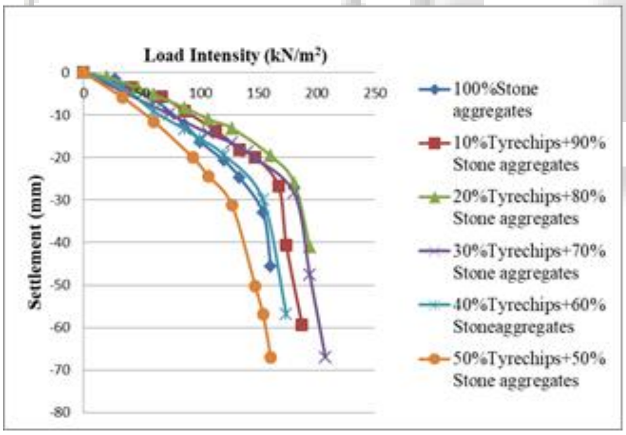

Fig. 3: Load settlement graph of two columns

C. Load –Settlement Characteristics of Three Columns

The load settlement curve for three columns of tyre chips-aggregate is shown in Fig.4. The curve indicates that load carrying capacity increases with the replacement of aggregates by tyre chips.[3]

It is also clear that there is a variation in load carrying capacity of the soil with the arrangement of columns. An increase in load carrying capacity in three column arrangement is due to more dense packing of columns.

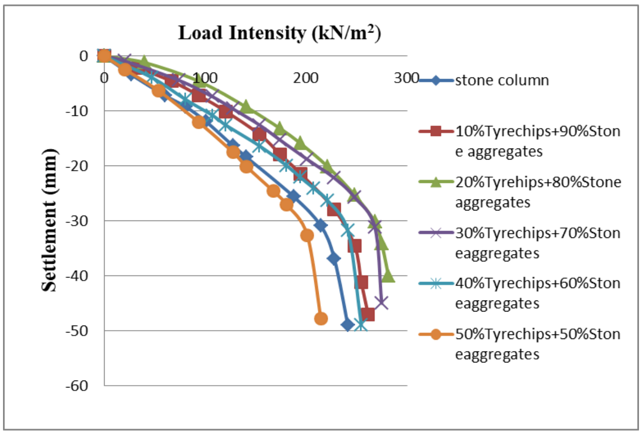

Fig. 4: Load Settlement Graph of Three Columns

Mix proportion of 70%S+20%T shows higher load carrying capacity in all different patterns of arrangement. Load intensity increases with increasing percentage of tyre chips upto 20%. Beyond 20% of tyre chips, load intensity is found to be decreasing. But a 40% replacement of stones with tyre chips has a higher load carrying capacity than stones alone. This clearly shows that waste tyre chips can be used as partial replacement of stone aggregates up to about 40% in stone columns.

V. CONCLUSIONS

From the analysis of results we can infer that, three column arrangement with stone and tyre chips mix shows the better performance. Stone columns (single and group) constructed with 80%S and 20%T shows the higher performance. There was an increase of 22.22% for single columns, 23.37%for two column arrangement and 22.66% for three column arrangement. Hence it can be concluded that tyre chips may be effectively utilized as column material in the place of conventional coarse aggregate for the improvement of clay.

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