Experimental investigation of using reclaimed asphalt pavement aggregate in scrap tire encased stone column

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ABSTRACT

Stone column is one of the cost effective techniques for improving soft soil layers. Since in the construction process of stone column, weak soil is replaced with stiffer material, appropriate method to bury the waste materials e.g. reclaimed asphalt pavement (RAP) and scrap tires, is to use as stone column materials. The aim of this study is the application of scrap tires for enclosing stone columns and RAP mixed with gravel for stone column, to provide an environmental friendly and cost-effective improvement method for weak layers. In order to investigate the behavior of such stone columns, experimental modeling of the unit cell consisting of a single stone column with reclaimed asphalt pavement as filler material and encasing it by scrap tires has been carried out. RAP contents of 0%, 25%, 50%, 75% and 100% are selected to investigate effects of different mixing ratios. Loading capacity tests were performed on encased and non-encased stone column specimens. Results of loading capacity tests show that encasing of stone columns with scrap tires improves the loading capacity significantly. On the other hand by increasing the RAP ratio from 0% to 100%, the stone column loading capacity changes. However no significant change in the bearing capacity has not been observed and therefore the use of stone column made of 100% or any percentage of RAP is reasonable.

KEYWORDS

Stone column, bearing capacity, reclaimed asphalt pavement(RAP), scrap tire, environment

1. Introduction

In recent years, environmental problems resulting from the disposal of scrap tires have become a global issue and the necessity of reusing them in new application has increased. Geotechnical engineering has a great potential to reuse these materials [1].

On the other hand due to breakdown of asphalt surfaces, in many cases, these materials are scratched off the road surface and stored around the road, therefore significant area of valuable lands will be occupied by these materials. Using reclaimed asphalt pavement (RAP) instead of clean gravel is a sustainable solution to reduce environmental concerns of natural resource limitations and waste recycling.

Stone column is one of the cost effective soil improvement techniques, in which usually 15-35% of weak soil is replaced by natural aggregates [2]. The stone columns increase the bearing capacity of the soft soil and reduce its settlement [3]. a stone column ultimately fails under the bulging if it has a length-to-diameter ratio greater than 3 [4]. Debnath and Dey by using geotextile sheets as reinforces on the entire length of the stone column, indicated that geotextile reinforce increases the bearing capacity of the stone column and reduces the bulging effect [5].

A suitable way to bury waste materials is to use them instead of natural aggregates of stone columns. Bottom ash [6] and tire shreds [7] are materials that have been used as a subtitute for stone column aggregates.

In this study, a series of unit cell tests have been carried out to investigate the effects of replacing stone column aggregates with RAP aggregates and using tires as encasing elements, on load–settlement characteristics of stone columns.

2. Experimental Program

In this investigation a cylindrical tank with a diameter of 228 mm, height of 330 mm was used for unit cell construction and a rigid steel plate with a diameter of 220 mm and a thickness of 20 mm was used as loading plate.

RAP contents of 0%, 25%, 50%, 75% and 100% are selected to investigate effects of different mixing ratios. Each sample is named RAPX where X represents the percentage of RAP in the sample. Prepared aggregate samples are shown in Figure 1.

11 unit cell loading capacity tests including 1 unreinforced clay loading test, 5 non-encased and 5 tire-encased stone column loading tests with different mixing ratio of aggregates were carried out. Thin walled, open-ended steel pipe with outer diameter of 78 mm and wall thickness of 0.7 mm was used for non-encased stone column construction. For the construction of the tire-encased stone column, instead of using the pipe, the space needed to pour the aggregates, was created by placing the tires on each other. The plan view of a tire-encased and non-encased stone column is shown in Figure 2.

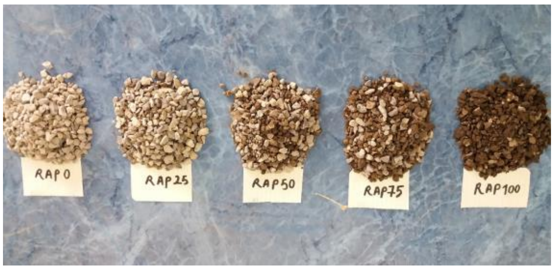

Figure 1. Prepared aggregate samples

(a) (b)

Figure 2. Plan view of unit cell: (a) tire-encased stone column; (b) non-encased stone column

A proving ring with a capacity of 30 kN was used to load unit cell. The load was applied at a constant strain rate of 1 mm/min. Each loading test was stopped at 32 mm displacement and load was read at every 1 mm displacement.

3. Results and discussion

Factor of improvement is defined as ratio of the ultimate loading capacity of the stone column with RAP aggregates to the bearing capacity of the non-encased stone column with natural aggregates, RAP0 [1]. Table 1 shows the factor of improvement of all samples. In this table, the letter E beside the symbol represents the encased sample.

Regardless of whether or not the stone column is tire-encased, the sample with 25% RAP content has a higher factor of improvement than other mixing ratios. By increasing the RAP content to more than 25%, the factor of improvement has decreased. Tire-encased stone columns have a factor of improvement greater than 1, regardless of the percentage of RAP content. Poor graded aggregates are commonly used for stone column filling materials to enhance drainage speed. There are many voids in the structure of poor graded aggregates due to the lack of many sizes in the gradation. The presence of these voids interrupts the transfer of force between the particles and thus reduces the loading capacity. In this study, by replacing 25% of the stone column material with RAP aggregates, about 7% of the sand aggregate smaller than 2 mm (minimum size of natural aggregates) and generally 10% of the sand aggregate was added to the matrix. These fine particles fill the voids between the coarse particles and increase the bearing capacity of the stone column by increasing the locking between the coarse particles and completing the force transmission paths.

Table 1. Factor of improvement of non-encased and tire-encased stone columns

Symbol	Factor of Improvement
RAP0	1
RAP25	1.27
RAP50	0.90
RAP75	0.83
RAP100	0.77
ERAP0	1.54
ERAP25	1.87
ERAP50	1.44
ERAP75	1.36
ERAP100	1.27

4. Conclusions

The following conclusions can be summarized based on the results of laboratory experiments:

- Loading capacity of stone column depends on the percentage of RAP aggregates in the mixture.
- Regardless of encasing stone column with tires, replacing 25% of natural stone column aggregates with RAP aggregates increases loading capacity. But as the percentage of RAP in mixture increases from 25% to 100%, the loading capacity decreases.
- The greatest reduction in bearing capacity due to the increase in RAP content is 23%, indicating that RAP aggregates can be an environment friendly alternative to natural aggregates of stone column.
- Regardless of the RAP content in the mixture, by confining the stone column with tires, the factor of improvement is more than 1, indicating that tire-encasement significantly increase the loading capacity of the stone column.
- The optimum percentage for replacing natural aggregates with RAP is 25% because of the mixture that has 25% RAP aggregates, increases the loading capacity by 27% and 87% in non-encased and tire-encased respectively.

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