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The use of steel waste as granular stone materials in stone columns along with geotextile in the direction of sustainable development

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ABSTRACT: The materials that make up the columns are generally sand, gravel or crushed stone, which are sometimes called stone or gravel columns. The implementation of this system is widely used in geotechnical engineering to increase bearing capacity and reduce settlement. The use of industrial wastes such as steel slag in soil stabilization can be an environmentally friendly, sustainable and cost-effective technique for solid waste disposal. Surveys show that many studies have been conducted on the bearing capacity and settlement of improved soils with stone columns with or without geosynthetic cover. However, a very limited number of studies on conventional stone columns and steel slag columns with or without confinement and geosynthetic cover have been investigated in laboratories under lateral loading. In this article, the lateral load capacity of steel slag granular sand-column environments has been investigated using a large-scale direct shear test device. The effect of column material type (steel slag and sand), column diameter, and changing the type of geosynthetic coating on the shear strength parameters of sand-column composites has been investigated. The experimental results show the effectiveness of using steel slag columns to improve the lateral load performance of sand, so that by increasing the diameter of the column in the sand environment from 5 to 25 cm, the percentage of maximum stress increases by 20 to 70% and also the percentage of internal friction angle increases by 200 Up to 800% compared to the sand environment without slag column was observed.

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1- Introduction

To date, many studies have been conducted on the use of industrial waste in civil engineering projects as a cost-effective and environmentally friendly alternative to construction materials. Today, to stabilize and improve the bearing capacity and reduce the settlement of soft and weak soils, piles and ordinary granular columns are used [1]. The most important factors affecting the performance of granular columns are: diameter, configuration and distance of columns, characteristics of aggregate materials, the relative density of column materials and lateral confinement caused by the surrounding soil [2-4]. However, the use of granular columns in soils with shear strength of less than 15 kPa may not be very effective due to insufficient lateral support provided by the surrounding soft soil [5]. This problem can be largely solved by adding a chamber to the granular column and using a geosynthetic cover, which leads to higher shear strength and prevents excessive column swelling [2]. This paper focuses on understanding the lateral load capacity of sand reinforced with steel slag column reinforced with different geosynthetic coatings. The new point of this research is the use of steel slag as granules in reinforced columns with different geosynthetic layers to modify weak sands. The effect of various types of geosynthetic cover models on the lateral load capacity of the composite sand and stone column with different diameters was investigated.

2- Laboratory program

In order to implement the research program, two types of materials are needed, the first category of host materials in which the columns are placed and the second category of materials used as column materials. In this study, uniform fine sand collected from Varzane region in Isfahan province was used as the host environment. For the second category, steel slag has been used as the column material. This slag is one of the side products of the electric arc furnace of Mobarake Steel Company, one of the largest steel producers in Iran. Granulation curves of materials are shown in Figure 1. Three types of geotextiles have been used to reinforce the slag column with different density percentages (250, 400 and 600 grams per square meter) in this research.

3- Performing tests

In this research, a series of large-scale direct shear tests were conducted to study the behavior of sand-column with geosynthetic cover with different percentages of density or

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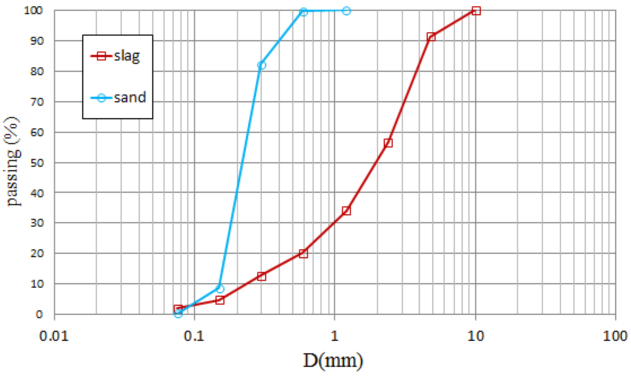

Fig. 1. Sand and slag grading curves

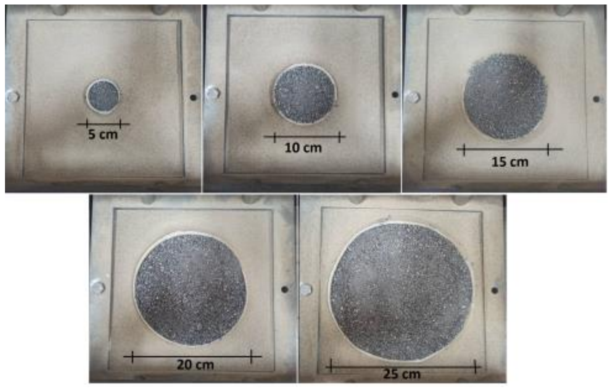

Fig. 2. Steel slag columns with various diameters in the box of the device

Table 1. details of the test program

Group	Geotextile weight (gr/m^2)	Column diameter (Cm)	Ar(%)
(N)	Without geotextile	5 , 10 , 15 , 20 , 25	2.2 , 8.7 , 19.6 , 34.9 , 54.5
(G2)	250		
(G4)	400		
(G6)	600		

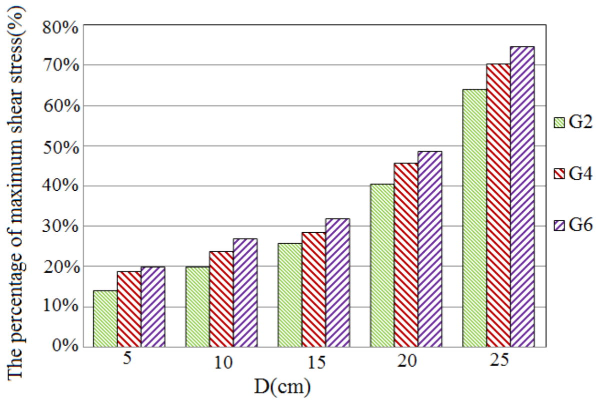

Fig. 3. The percentage of the maximum shear stress of group samples compared to the maximum stress of sand

without it. For this purpose, a large-scale direct shear machine with box dimensions of 30×30 cm^2 and depth of 14 cm was used. In this investigation, the behavior of steel slag column in sand was evaluated based on ASTM D3080 standard. The samples were cut under three different normal stresses (33, 65 and 130 kPa) and uniform displacement control with a constant strain rate of 1 mm/min.

4- Preparation and testing program

In this study, large-scale direct shear tests were conducted to investigate the behavior of sand due to the change in column diameter and different geotextile models, and the details of the test program are provided in Table 1. The effect of column diameter or surface replacement ratio (Ar) on column shear strength parameters was also investigated. As shown in Figure 2, steel slag columns in different diameters (5, 10, 15, 20, and 25 cm) were placed in the center of the machine box with different models of geosynthetic cover and without it (Table 1).

5- Results and Discussion

The results of the tests presented in this section include the effect of different parameters such as the diameter of the column, the use or non-use of geotextile, as well as the effect of the density and model of the geotextile cover on the shear strength. The percentage of the maximum shear stress of each group of tests (G2, G4, G6) compared to the maximum stress of sand can be seen in Figure 3..

Figure 4 shows the variation of the angle of internal friction for the enclosed columns of groups (N,G2,G4,G6) with the replacement ratio (Ar), which is defined as the ratio between the area of the steel slag column. Figure 5 shows the cohesion value of the sand-slag column composite against the area replacement ratio (Ar) for groups (N,G2,G4,G6) at different levels of normal stress.

6- Conclusions

The use of industrial waste in civil engineering applications as economical and environmentally friendly building materials. This study is focused on the use of steel slag materials as granular column materials for improving loose sands. Based on the investigations, the following results have been obtained:

1- As it has been determined from the results of this research, the use of slag in the stone column will increase the shear resistance parameters and increase the value of the internal friction angle. This material, if it replaces stone materials, is very suitable from the point of view of the environment, because it will cause the consumption of industrial waste.

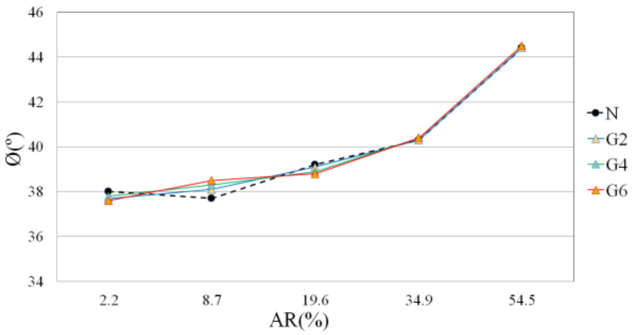

Fig. 4. Variations of internal friction angle of slag-sand column composite

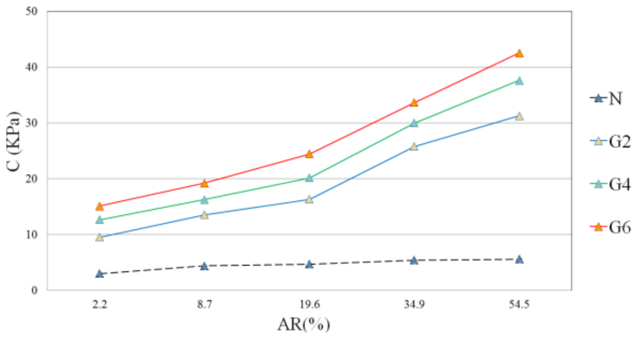

Fig. 5. Changes in the cohesion value of the slag-sand column composite

2-Examining the results shows that simply confining the column in the soil can have a great effect on increasing the maximum stress value and the higher the density, the more this increase will have a slower slope

3- The presence of a slag column increases the angle of internal friction, and the enclosing layer does not have much effect on the trend of this parameter, but it increases the cohesion of the aggregates of the column and increases the shear resistance parameters.

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