

Effect of the Cylindrical Reinforcing Element's Filling Materials on the Soil's Resistance

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Abstract

In this paper a laboratory study has been carried out on the effect of changing the type of soil filling cylindrical reinforcing elements from SM to GM on behavior of sandy soil. In this study the primary tests for evaluation of the impact of reinforced sand and gravel columns with diameters of 5 cm and heights of 15 cm subjected to vertical stresses of 50, 100, and 150 KPa were carried out in a large-scale direct shear apparatus (300×300×150 mm). Results showed that the shear stress and settlement of the reinforced sample with geogrid and a gravel column increases by 45.4% and decreases by 23.9% respectively compared to the non-reinforced sample.

Keywords: Reinforced Column, Large-Scale Direct Shear Apparatus Test, Shear Stress, Settlement

1. Introduction

Soil is a material that resists properly when subjected to pressure and shear stress [1]. However it does not show an acceptable resistance when subjected to tensile forces [2]. Use of auxiliary elements in reinforcing and refining the soil has caught people's attention from for a long time now [3]. Reinforced soil is a compound building material that utilizes elements with tensile resistance as reinforcers in the soil bulk [4].

Internal stresses exerted on a reinforced soil bulk by external forces cause frictional interactions between the soil and the reinforcing materials. Therefore the stresses in the soil bulk transfer to the reinforcing materials through friction or agglutination. This way, the reinforcing materials resist lateral deformation and this results in an increase in the load-bearing capacity of the reinforced soil bulk [5].

Theoretical and empirical studies by various researchers show that in high confining pressures, the reinforced soil's failure is due to an increase in the reinforcing materials' failure. This causes an increase in the soil's apparent cohesion. In low confining pressures, the reinforced soil's failure is due to slippage of reinforcing materials against their surrounding soil. This causes an increase in the internal friction angle of the soil [6].

2. Research goals

The purpose of this study is investigating the effect of changing the type of the soil filling the cylindrical reinforcing element from SM to GM on behavior of the sandy soil in the region of Imam Reza holy shrine in Mashhad, Iran using a large-scale direct shear apparatus. In this study the method of conduct for the primary tests is utilizing a large-scale direct shear stress (300×300×150 mm) [7].

3. Utilized Materials

In this research the non-reinforced and reinforced samples with cylindrical reinforcing element have been subjected to loading in large-scale direct shear apparatus, in which the reinforced samples are made of soil and the reinforced element with properties as follows [8].

3.1. Soil

The soil surrounding the reinforcing element is of the silty sand (SM) type and the soil filling the reinforcing element is of the silty sand (SM) and silty gravel (GM) types.

A summary of the sandy and gravel soils' properties is set out in tables 1 and 2 and figures 1 and 2.

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Table-1: Physical and mechanical properties of the studied sand soil

Soil type	Test type	ASTM Standard	Value
SM	Moisture	ASTM D2216	5 %
	Specific density	ASTM(D 854)	2.506
	Wet density	ASTM 4914	kN/m ³ (18)
	Adhesion resistance	ASTM D3080	KPa (13)
	Internal friction angle	ASTM D3080	22°

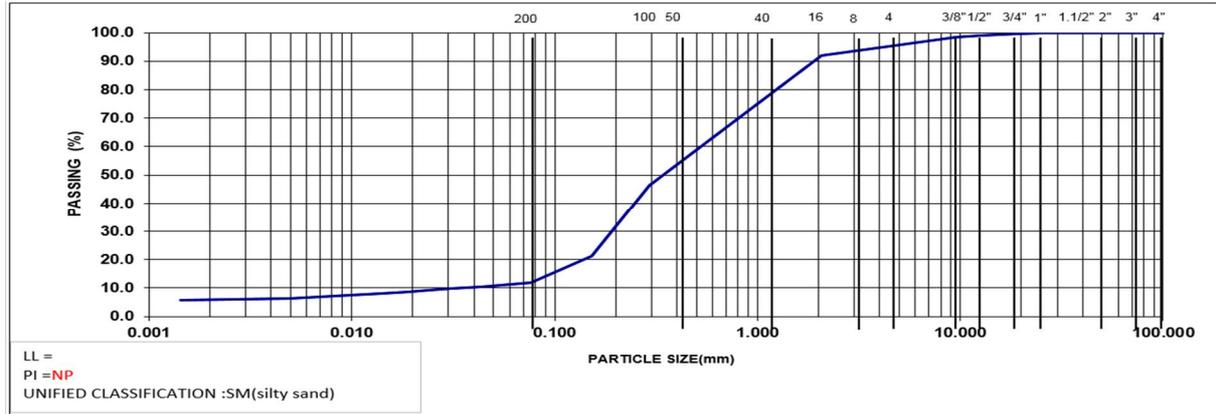


Figure 1: Grading curve in the studied sandy soil

Table 2: Physical and mechanical parameters of the studied gravel soil

Soil type	Test type	ASTM STANDARD	Value
GM	Moisture	ASTM D2216	3.5%
	Specific density	ASTM(D 854)	۲.۴۶۸
	Wet density	ASTM 4914	۱۹ (kN/m ³)
	Adhesion resistance	ASTM D3080	4 (KPa)
	Internal friction angle	ASTM D3080	34°

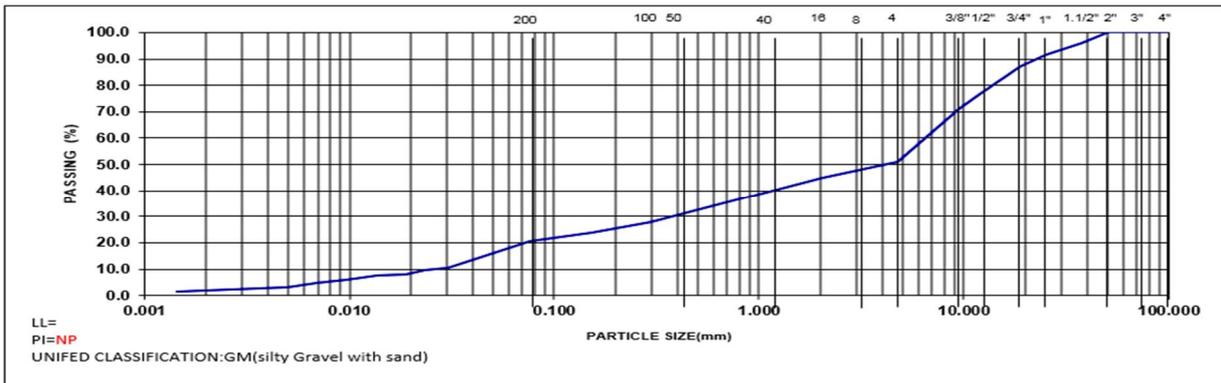


Figure 2: Grading curve of the studied gravel soil

3.2. The reinforcing element

To build the laboratory model, a reinforced cylindrical element of geogrid which is one of geosynthetics was used. The mechanical properties of the utilized geosynthetic can be seen in table 2.

Table 3: Geogrid mechanical properties

row	Sample code	Tensile resistance(N)	Sample width (%)	Tensile resistance (N/m)
1	Crosswise sample	71.81	26.5	2710
2	Longitudinal sample	66.36	25.5	2602
3	Average	-	-	2656

4. Producing the samples

Preparation and production steps of non-reinforced and reinforced samples with reinforcing elements before conducting the test using large-scale direct shear apparatus are as follows:

1. The dried sandy soil was passed through a 3.4 inch sieve according to the required volume for the large-scale direct shear apparatus.
2. 5% water added to the soil to achieve natural moisture. In order to achieve uniform moisture, water and soil were intermixed appropriately.
3. The prepared soil was divided to three equal portions and then the first layer was put in the shear loading box and was pounded as specified and was scratched by a scraper before putting in the next layer to increase the next layer's compressive attachment with the

bellow layer. The two other layers were added and compressed in the same way.

4. In this step, as is shown in figure 3 (D), we specify the shear loading box center and then a cylinder which is made of stainless steel plate will pound vertically in the shear loading box. Then the soil inside the cylinder is extracted by a spoon and afterwards we take out the metal cylinder. Finally the geogrid which was made as a cylinder was put into the dug hole.
5. After putting the geogrid in the dug hole, the SM or GM soil was put in the reinforcing cylinder in three layers and was compressed. The three layers were pounded in such a way as to fill the cylinder volume with the required specific weight and at the same level as the surrounding soil of the reinforcer.

The building steps of the physical model are shown in figure 3.

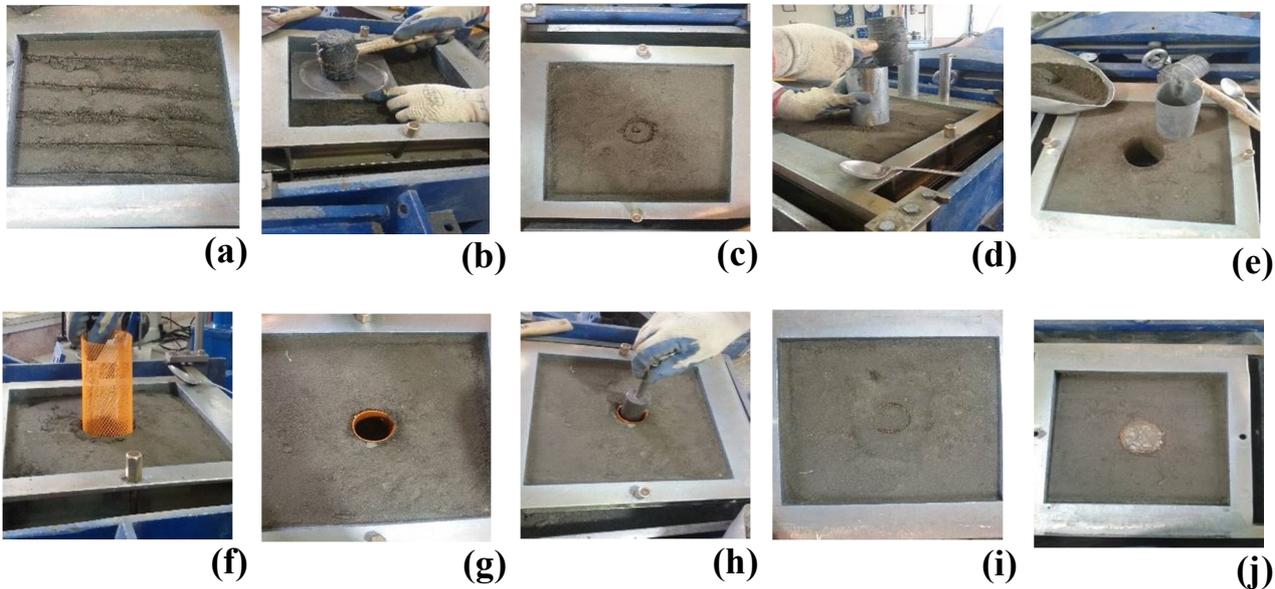


Figure 3- Building steps of the physical model in laboratory

5. Laboratory examinations

In this study the effect of changing the type of the soil filling the cylindrical reinforcing column with a diameter of 5 cm and a height of 15 cm from SM to GM on shear stress, settlement, and parameters of shear resistance compared to the non-reinforced sample was investigated utilizing a large-scale direct shear apparatus. Sections of the laboratory sample can be seen in figure 4.

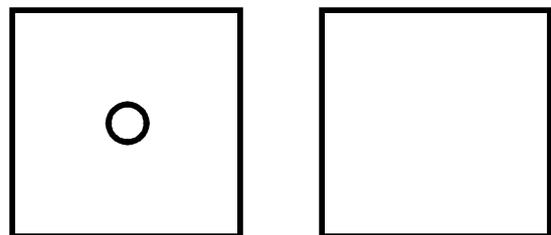


Fig 4. Sections of non-reinforced and reinforced samples in the large-scale direct shear apparatus

It should be noted that the large-scale direct shear tests (300×300×150 mm) were conducted with 50, 100, and 150 KPa and a speed of 1 millimeter per minute. The variations in the shear stress and settlement against horizontal displacement are shown in figures 5-10 and the failure envelope is illustrated in figure 11.

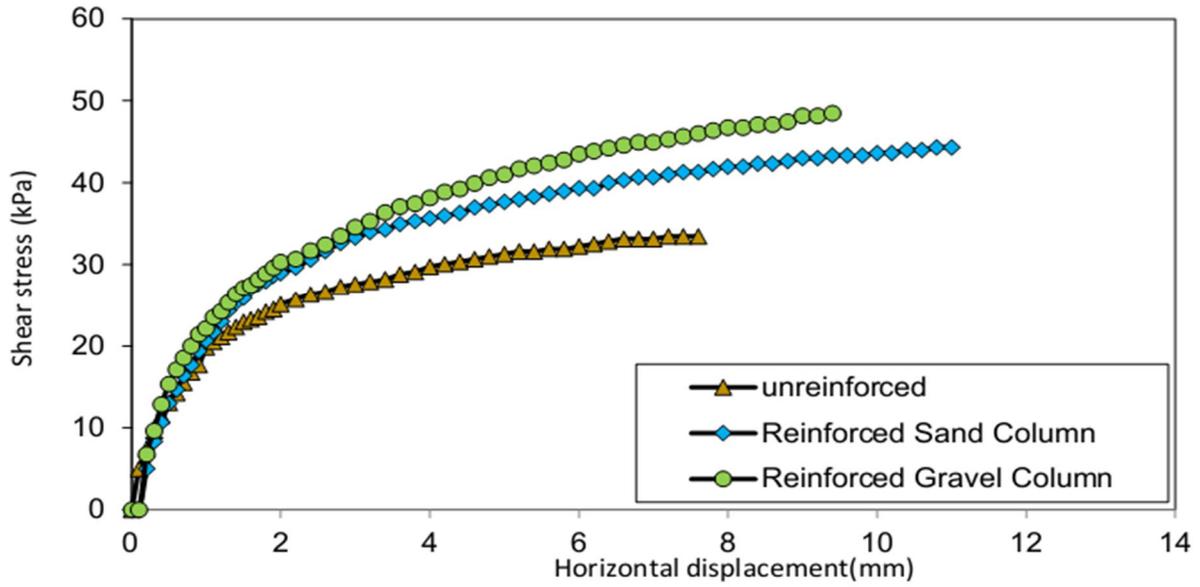


Fig. 5. Variations in horizontal displacement –The shear stress of non-reinforced and reinforced sand subjected to a vertical stress of 50 KPa

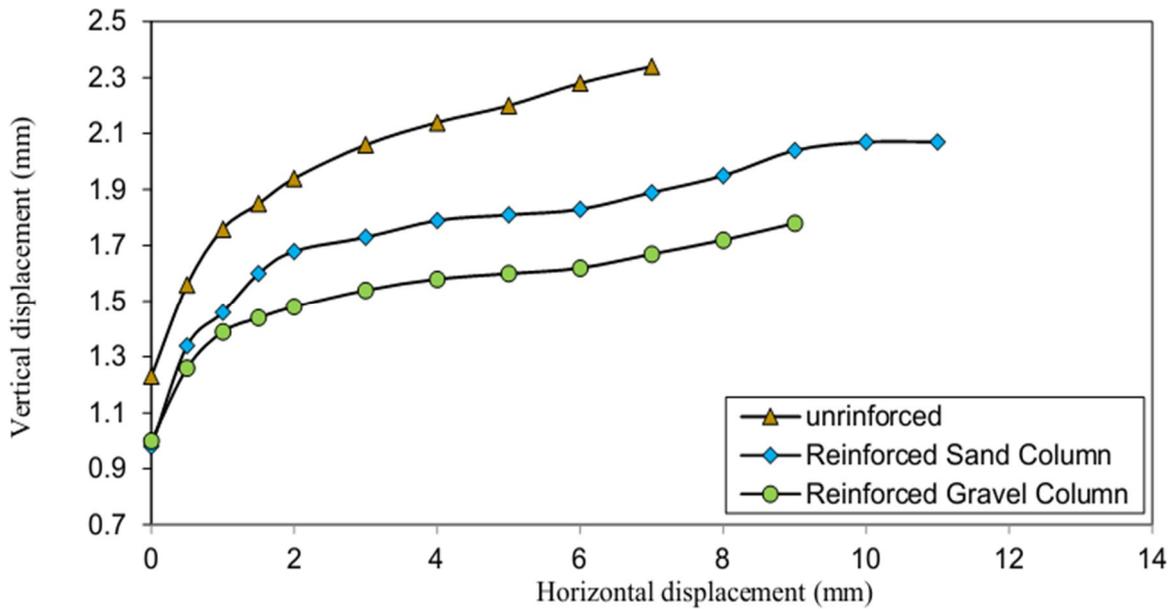


Fig. 6. Variations in horizontal displacement – The settlement of non-reinforced and reinforced sand subjected to a vertical stress of 50 KPa

As can be seen in figures 5 and 6, when subjected to a vertical stress of 50 KPa, the maximum shear resistance at the instant of failure and the settlement of the reinforced sample with geogrid and a sand column increases by 33.3% and decreases by 12.8% respectively compared to

the non-reinforced sample. While the maximum shear resistance at the instant of failure and the settlement of the reinforced sample with geogrid and a gravel column increases by 45.4% and decreases by 23.9% respectively compared to the non-reinforced sample.

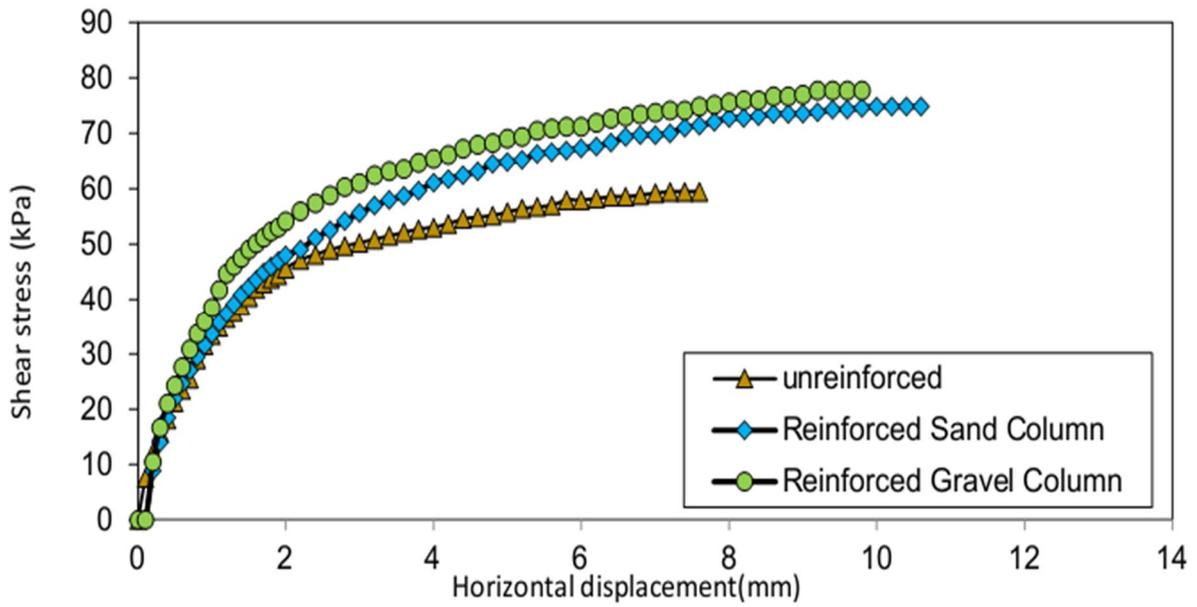


Fig. 7. Variations in horizontal displacement – The shear stress of non-reinforced and reinforced sand subjected to a vertical stress of 100 KPa

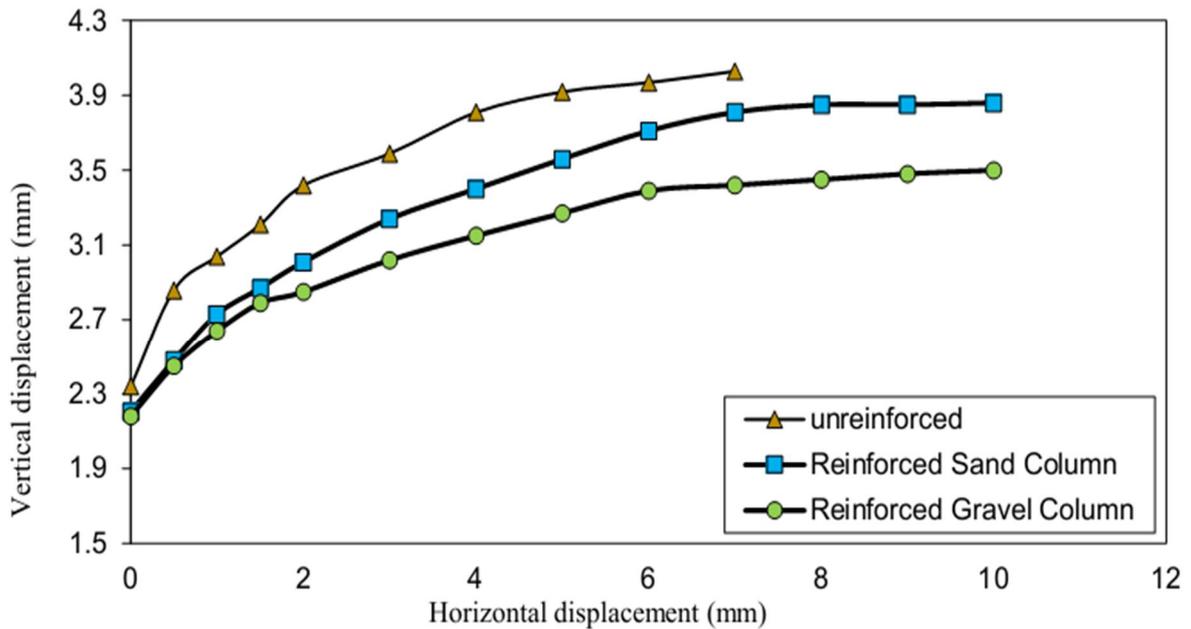


Fig. 8. Variations in horizontal displacement – The settlement of non-reinforced and reinforced sand subjected to a vertical stress of 100 KPa

As can be seen in figures 7 and 8, when subjected to a vertical stress of 100 KPa, the maximum shear resistance at the instant of failure and the settlement of the reinforced sample with geogrid and a sand column increases by 23.7% and decreases by 5.5% respectively

compared to the non-reinforced sample. While the maximum shear resistance at the instant of failure and the settlement of the reinforced sample with geogrid and a gravel column increases by 34% and decreases by 13.1% respectively compared to the non-reinforced sample.

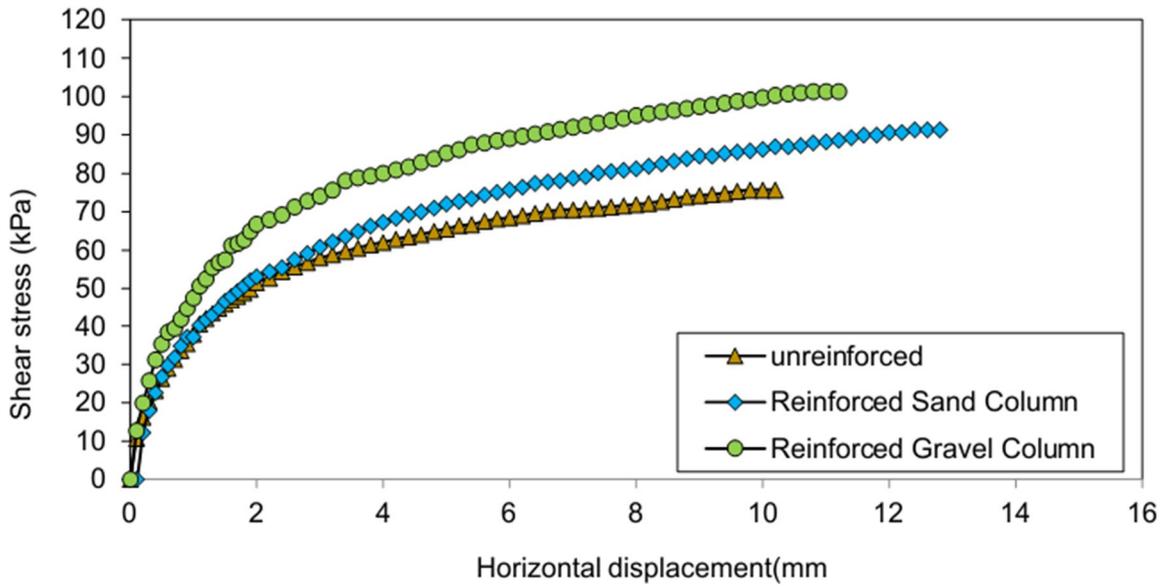


Fig. 9. Variations in horizontal displacement – The shear stress of non-reinforced and reinforced sand subjected to a vertical stress of 150 KPa

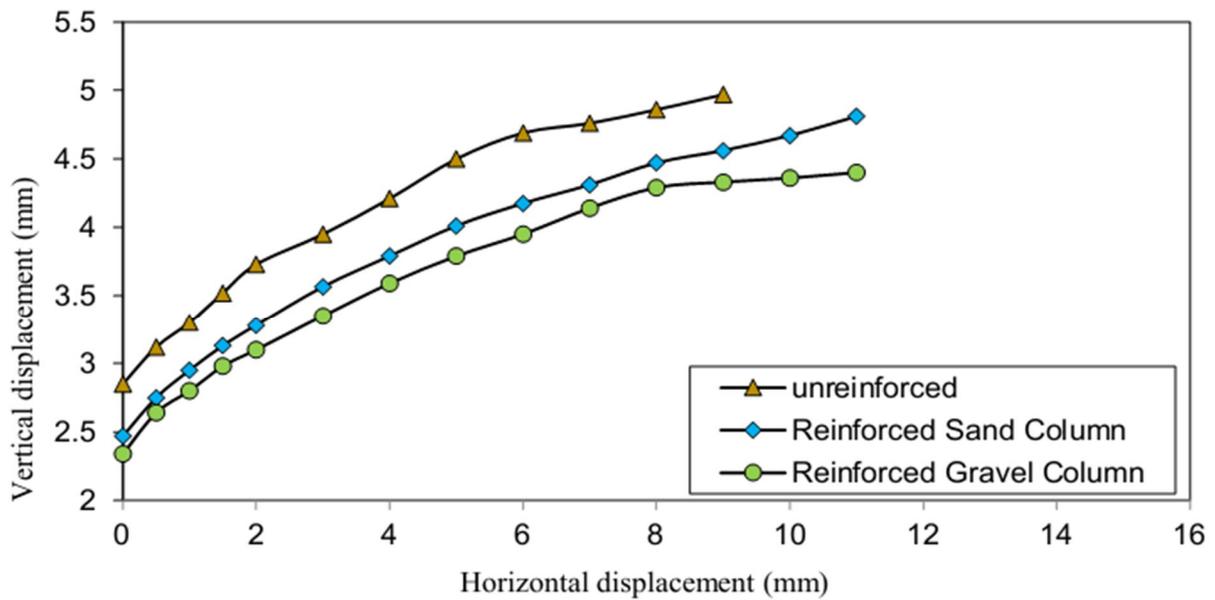


Fig. 10. Variations in horizontal displacement – The settlement of non-reinforced and reinforced sand subjected to a vertical stress of 150 KPa

As can be seen in figures 9 and 10, when subjected to a vertical stress of 150 KPa, the maximum shear resistance at the instant of failure and the settlement of the reinforced sample with geogrid and a sand column increases by 21.3% and decreases by 3.2% respectively compared to the non-reinforced sample. While the

maximum shear resistance at the instant of failure and the settlement of the reinforced sample with geogrid and a gravel column increases by 30.26% and decreases by 11.5% respectively compared to the non-reinforced sample.

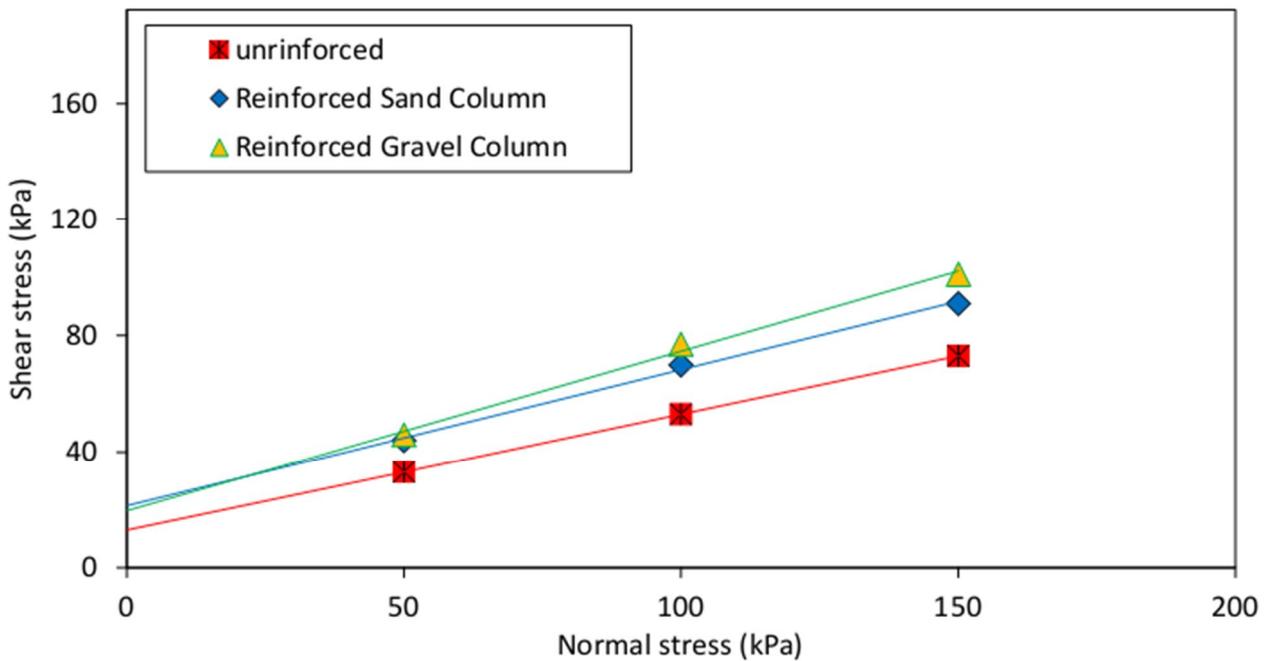


Fig 11. The failure envelopes of the non-reinforced and reinforced sand

Fig 11.

According to figure 11, the internal friction angle and the apparent cohesion of the reinforced sample with geogrid and a sand column increase by 14.54% and 61.53% respectively compared to the non-reinforced sample. While the internal friction angle and the apparent cohesion of the reinforced sample with geogrid and a gravel column increase by 31.36% and 53.84% respectively compared to the non-reinforced sample.

6. Conclusion

Based on the examinations in this research the following results were reached:

1. As can be seen, use of a cylindrical reinforced column results in an increase in shear resistance, a decrease in settlement, and an increase in parameters such as the sample's internal friction angle (ϕ_r) and apparent cohesion (c_a).
2. By changing the type of the soil filling the reinforcer from SM to GM, the shear resistance, internal friction, and apparent cohesion increase considerably.
3. By changing the type of the soil filling the reinforcer from SM to GM, the settlement decreases considerably.
4. Use of a cylindrical reinforced sand column has a greater effect on increasing the shear stress than decreasing the settlement. On the other hand use of a reinforced gravel column has a simultaneous effect on increasing the shear resistance and decreasing the settlement.
5. A much larger horizontal displacement is needed for the reinforced sample to fail compared to the non-reinforced sample.

6. For the samples reinforced by sand and gravel cylindrical columns by increasing the vertical stress, the increasing trend of the shear resistance and the decreasing trend of settlement in the reinforced sample reduces compared to the non-reinforced sample.
7. The greatest increase in the shear resistance is 45.4% in the case that the sample is reinforced by a gravel column and is subjected to the vertical stress of 50 KPa. In this case, the sample's settlement decreases by 23.9%.
8. The greatest increase in cohesion is 61.53% and in internal friction angle it is 31.36% for the cases that the sample is reinforced by a sand column and a gravel column respectively.

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