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EXTENDED ABSTRACT

Experimental Evaluation of The Behavior of Geogrid-Reinforced Sand Placed on Top of Twin Voids

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1. Introduction

Foundation settlement is influenced by a number of variables, including soil type, structure load, environmental influences, and subsurface voids. Whether human-made or natural, underground voids can significantly reduce the soil's load-bearing capacity, leading to excessive settlement and possible structural damage. Using stabilizing elements to reinforce soil is an effective way of reducing these effects and improving soil capacity. Studies on the performance of foundations over twin voids, particularly in reinforced soil, are still limited, despite the fact that most prior research has concentrated on foundation behavior over a single void. The behavior of a strip foundation lying on sandy soil reinforced with geogrid and featuring twin voids is examined in this study. Moreover, failure surfaces were investigated using the Particle Image Velocimetry (PIV) method.

2. Methodology

2.1. Geogrids and Voids

Based on earlier research, a geogrid with a constant width of 50cm was used in this investigation to reinforce the soil. According to preliminary testing, there was no noticeable reduction in bearing capacity when the geogrid width was increased to 100cm (5 times the footing width). Additionally, flexible plastic pipes measuring 9cm in diameter and 1.8 mm in thickness were used to simulate subsurface voids. These pipes were regarded as voids because of their extremely low axial and bending stiffness.

2.2. Soil

Dry sand from the Sufian region of East Azerbaijan Province in Northwestern Iran was used for all experiments. The Sufian sand samples have undergone a series of tests to evaluate its geotechnical characteristics and strength characteristics. ASTM D3080-04 for the direct shear test, ASTM D698 for the compaction test, ASTM D854 for the calculation of specific gravity, and ASTM D2487 for the classification of soil were the standard procedures used for these tests.

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2.3. Procedure for conducting the tests

The laboratory-scale experiments in this study were carried out using a scale reduction factor of 1:7.5. Consequently, a factor of 7.5 was applied to all modeled dimensions in the present investigation. The physical modeling chamber utilized for the tests was 130cm in length, 50cm in width, and 80cm in height. The modeling procedure, which included placing soil, compacting soil layers, positioning pipes, and installing reinforcements, was the same for all tests. Each soil layer was compacted after deposition, and the soil was placed in 10cm thick layers with a constant weight to guarantee uniform relative density throughout all soil layers. Until the pipe placement locations were reached, this process was repeated. The pipes were eventually placed 30 and 40 centimeters above the chamber's bottom. After the pipes were positioned, compaction and soil deposition continued until the installation of the reinforcement. The last soil layers were placed in, the reinforcement layers were installed, and the strip footing was placed on top of the soil. Two strain gauges were installed on the footing to track its displacement. A 3-ton loadcell was also employed for force measurements, and force values were obtained using an indicator unit. A constant strain rate loading approach was used to attain the highest level of precision and keep the loading rate constant throughout all experiments. 10 steps of 5mm each were used to achieve the footing's total applied settlement of 5cm. Each experiment was carried out in 11 phases, with incremental loading implemented in the following phases after no load was applied in the first. To facilitate PIV analysis, images were taken from the soil chamber's front face during each of the 11 phases.

3. Results and discussion

3.1. Capability of load bearing in soil's loose state

For loose soil conditions, Fig. 1 shows the load-settlement curve for unreinforced and geogrid-reinforced soil placed above twin voids. The results displayed in Fig. 1 demonstrate that the soil reinforced with a single geogrid layer embedded at depths of 3.5cm and 7 cm from the ground surface increased in bearing capacity by 16.5% and 25.1%, respectively, under the conditions of h/B=1 and S/B=0.6. Furthermore, in the same conditions, adding two geogrid layers at these depths increased the bearing capacity of unreinforced soil by 34.9% and 45.1%, respectively.

A review of previous research by Demirdöğen et al. (2024), Sireesh et al. (2009), and Moghaddas Tafreshi et al. (2011) also revealed a similar trend in the load-bearing behavior of reinforced sands with loose relative density, showing that the load-bearing capacity of geosynthetic-reinforced sands with low relative density was lower than that of sands with high relative density. Additionally, Moghaddas Tafreshi et al. (2011) reported that adding more reinforcement layers improved the system's load-bearing capacity in soils with lower relative densities.

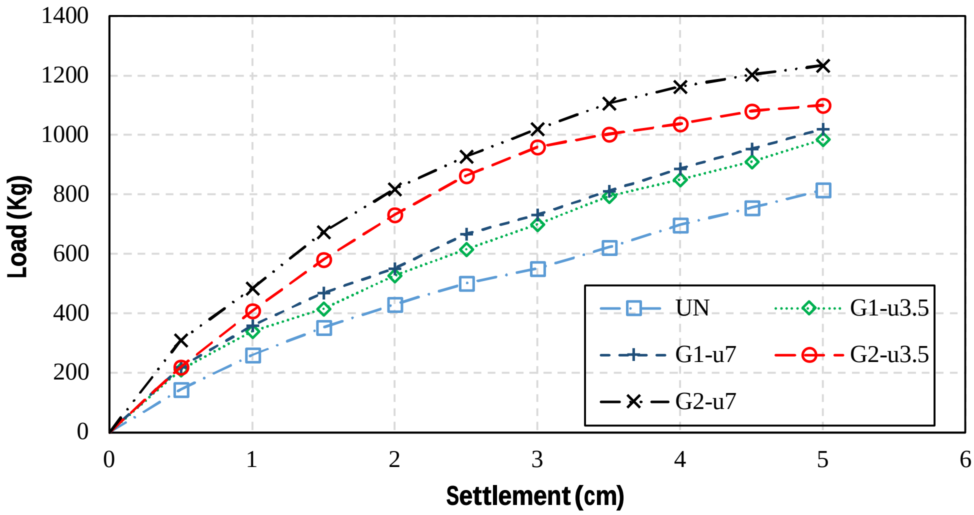

Fig. 1. The load-settlement curve of loose soil with twin voids with ratios of h/B=1 and S/B=0.6

3.2. Capability of load bearing in soil's dense state

According to the results shown in Fig. 2, the addition of 1 and 2 geogrid layers embedded at a depth of 3.5cm, respectively, increased the bearing capacity of dense reinforced soil by 7.3% and 21.4% when compared to unreinforced soil under the conditions of h/B=1.5 and S/B=0.8. Additionally, the bearing capacity of reinforced soil with one and two geogrid layers embedded at a depth of 7cm increased by 12.8% and 51.8% when compared to unreinforced soil.

When the first geogrid layer's embedment depth is increased to 7cm (u/B=0.35), the overburden pressure on this layer increases, improving the frictional resistance between the geogrid and the sand and increasing the reinforced soil's bearing capacity. Tafreshi and Khalaj (2008) found that when the reinforcement embedment ratio is less than 0.35 (u/B<0.35), the soil layer between the reinforcement and the footing does not produce enough overburden pressure to develop effective frictional resistance at the sand-geogrid interface.

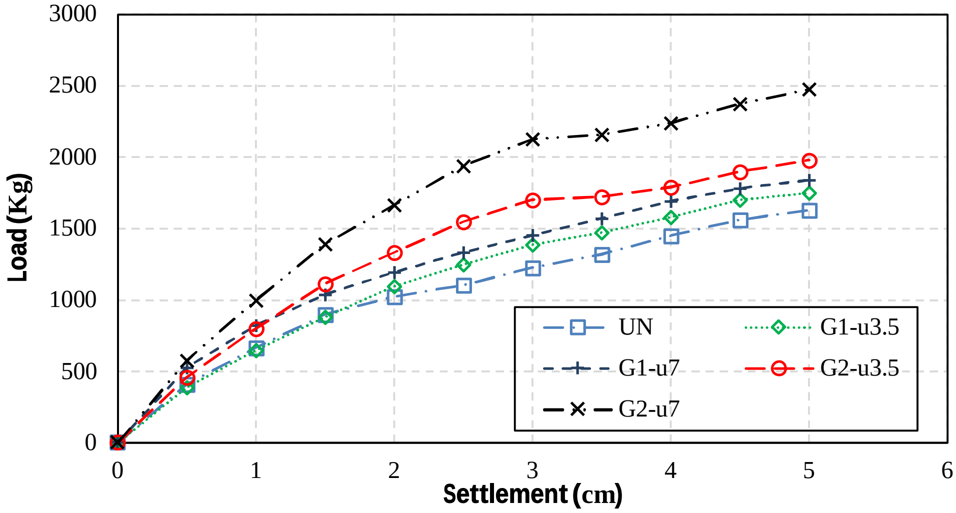

Fig. 2. The load-settlement curve of dense soil with twin voids with ratios of h/B = 1.5 and S/B = 0.8

3.3. Changes in horizontal displacement of voids

In all investigated cases (Fig. 3.), the horizontal displacement of the voids decreased when the embedment ratio of voids (h/B) was increased from 1 to 1.5. Because there is more soil above the voids, more of the displacements brought on by loading are received. The rate of horizontal displacement changes also decreased when the void spacing ratio (S/B) increased from 0.6 to 0.8. A larger soil volume results from increasing the distance between the voids, which reduces the load that is shared to them and, as a result, minimizes their horizontal displacement. This effect was more noticeable in thick sand because the higher relative density increases the soil's internal friction angle, which improves particle interlocking and eventually lowers soil displacement.

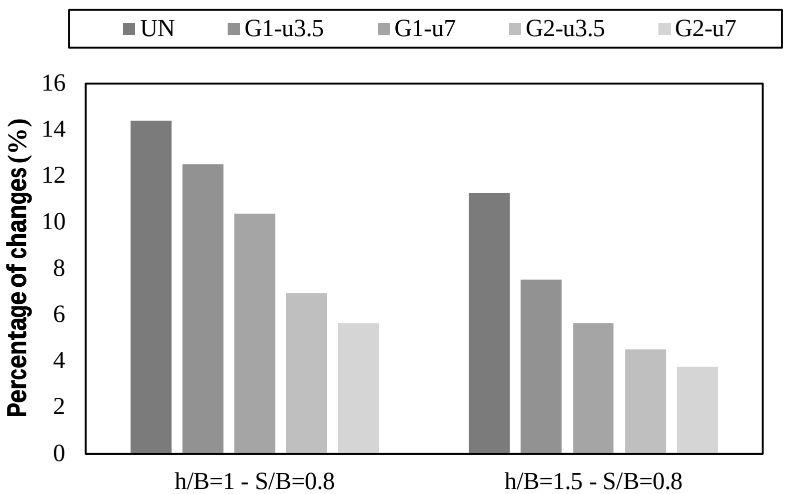

Fig. 3. Graph of the percentage variations in the horizontal spacing between voids in dense soil with reinforcement under different conditions

4. Conclusions

The behavior of soil with twin voids under reinforced and unreinforced conditions was investigated in this study through 40 tests on both unreinforced and geogrid-reinforced sand. The effects of several parameters, such as the number of geogrid layers, the embedment depth and spacing of geogrid layers, the void embedment depth, and the soil relative density, were assessed. The results showed that:

1. The load bearing capacity increased and the horizontal displacement of the voids decreased as the void spacing ratio (S/B) increased.
2. Higher bearing capacity and reduced horizontal displacement of the voids were the outcomes of increasing the void embedment ratio (h/B) in all experiments.
3. By improving the resistance of the soil beneath the footing, adding more geogrid layers greatly increased the bearing capacity of reinforced soil; the test with two geogrid layers (G2-u7) showed the greatest improvement, with the bearing capacity of dense reinforced sand increasing by 51.8% in comparison to unreinforced soil.
4. In all tested circumstances, increasing the soil's relative density from 35% to 73% increased its bearing capacity and decreased the voids' horizontal displacement. Increased internal friction between soil particles and a decrease in gaps between the soil particles were associated with improving the system's ability to withstand loads.