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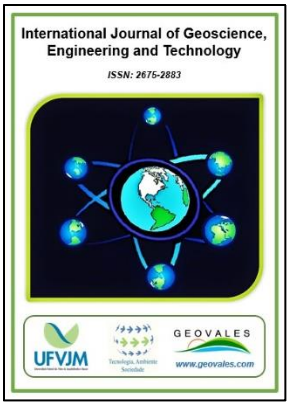

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Analysis of the Use of Geogrid for Soil Reinforcement in the Application of Surface Foundation

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Abstract

With the development of constructions, engineering often faces the challenge of building on land with low support capacity. A solution for these cases is the soil reinforcement with geosynthetics, which by increasing the load capacity of soil, enables the use of shallow foundations. In view of this, the present work evaluates the use of the geogrid as a geotechnical reinforcement material. Therefore, a static load proof tests on the plate was performed in sandy soil, in its natural state and reinforced with the geogrid. The soil strengths were compared in both cases and the strength gained with the use of the geogrid was estimated. The results showed that the use of the geogrid could increase soil resistance by over 90%, indicating that it is an excellent reinforcement material for the soil.

Keywords: Geosynthetic, Shallow Foundations, Reinforced Soil.

1. Introduction

The increase in demand for terrain use has led to a reduction in land for construction and, with it, the need for greater use of problematic areas for construction purposes. In this context, it is common to find in nature portions of soil that do not present ideal conditions of resistance, which results in the need to execute deep foundations to support the loads generated by the construction. Deep foundations are more expensive, require more sophisticated equipment and longer execution time, in addition to requiring greater excavation depths, which, depending on the method used, increases the risk for workers on site.

An alternative solution to the problem of land with low support capacity is the reinforcement of the more superficial layers, which allows the reduction of the foundation structure, enabling the use of superficial foundations for land that would normally be unfeasible. In this context, the use of geosynthetics as soil reinforcement emerges, offering economical and technically advanced solutions for the execution of foundations. According to Lopes (2019), there are many benefits that the use of geosynthetics as soil reinforcement can bring, their use results in less complex construction techniques, less excavation and transport volume, lower cost of equipment, and finally, less workmanship. Thus, presenting a better cost-benefit ratio.

Some studies have already been developed to evaluate the effects of the geogrid as reinforcement. Fattah, Hassan and Rasheed (2018) carried out several laboratory experiments using PVC pipes buried in a middle layer of sand, below a sub-base layer, reinforced with geocells, the results showed that the geogrid was able to reduce the pressure vertical that reaches the tube at 41%. Ahmad (2022) evaluated the effect of geogrid reinforcement on the load pressure settlement response of shallow footings, the results indicated that geogrid sheets were able to increase stiffness and reduce soil settlement. Akbar, Bhat and Mir (2021) investigated the effect of a bitumen coated geogrid reinforcement on the bearing capacity rate of a shallow foundation, it was found that the bearing capacity rate of reinforced clay increased from 20 to 55% in relation to unreinforced clay

Therefore, the importance of studying the characteristics and properties of geosynthetics is justified in order to assess their applicability in reinforcing low- resistant soils, as well as developing methods for dimensioning according to the characteristics of the works and materials used (Vertematti, 2015). Thus, the present work evaluates the strength of soil reinforced with the use of a geogrid in the application of superficial foundations. Characterization tests and static load proof tests were carried out on the plate in the direct foundation, in the soil in its natural state, and soil enveloped with the geogrid, and then the results presented were compared, verifying whether the combination of soils + geogrid could be used as a support for building foundations.

1.1. Geosynthetic Materials

According to NBR 12553, geosynthetics are industrialized polymeric products, synthetic or natural, which are developed for geotechnical works to bring performance improvements, being able to perform functions of reinforcement, filtration, drainage, protection, separation, waterproofing, and control of surface erosion.

In recent years, the use of geosynthetics has intensified as a replacement for traditional materials or reinforcement of natural materials, a is due to the fact that they present themselves as an excellent alternative geotechnical solution, being less sensitive to differential settlements in the structure, resulting in savings in the construction process and minimizing environmental effects, likewise, being simple and quick to install, enabling the replacement of noble materials and enabling the execution of certain constructions (Marques, 2008), (Araújo, 2008), (Teixeira, 2003).

The classification of geosynthetics is according to their intended function, which may be geotextile, geomembrane, geocomposite, geogrid, geocell, among others (Figure 1). Geogrids and geotextiles are the geosynthetics often used in soil reinforcement, they are materials that offer good tensile strength and have adequate interaction with the surrounding soil (Teixeira, 2003). In this research, performing geogrids as soil reinforcement will be evaluated.

Geogrids are flat structures as grids whose openings allow the interaction of tensile-resistant elements in the environment in which they are confined, they are said to be unidirectional when they have high tensile strength in only one direction and bidirectional when they have high tensile strength in both directions main. Geogrids can also be classified according to the confection process, and can be extruded, welded, or woven (Lopes, 2019) (Figure 2). In this work, the welded geogrid will be evaluated, which is made from the orthogonal weld of geostrips composed of bundles of synthetic textile filaments.

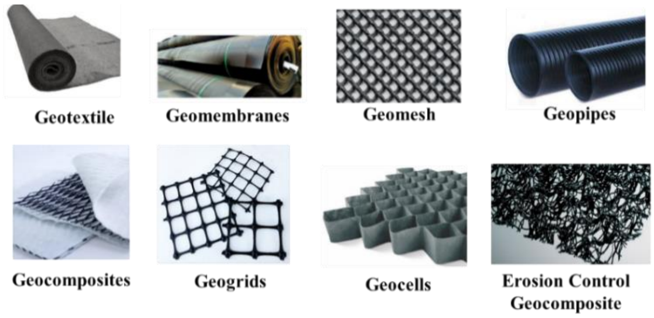

Figure 1 – Examples of geosynthetics.

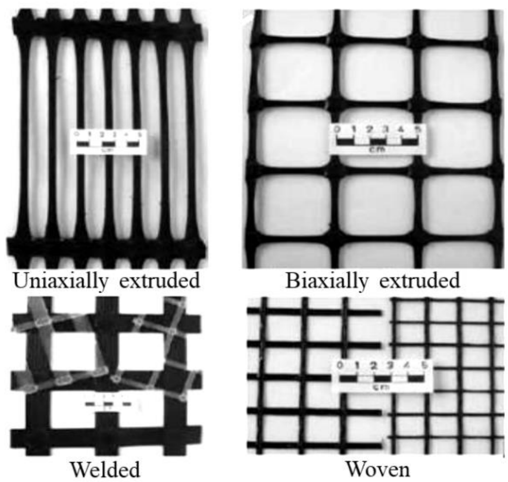

Figure 2 – Types of Geogrid (adapted from Borges, 2012).

1.2. Soil Reinforcement with Geogrid

The reinforcement of soil with the geogrid comprises positioning it in certain regions of soil to cause a favorable redistribution of stresses, from the combination of the compressive strength of soil with the tensile strength of the geogrid, resulting in a structure that is internally resistant to large loads without suffering damage related to excessive deformations (Futai and Neto, 2016).

As far as reinforcement performance terms are concerned, geogrids, in moreover to providing greater tensile strength, improve direct shear strength properties, and generate pullout strength. Besides increasing the strength of the material, including the geogrid, provides a decrease in compressibility, allowing the application of higher loads (Figure 3) (Borges, 2012).

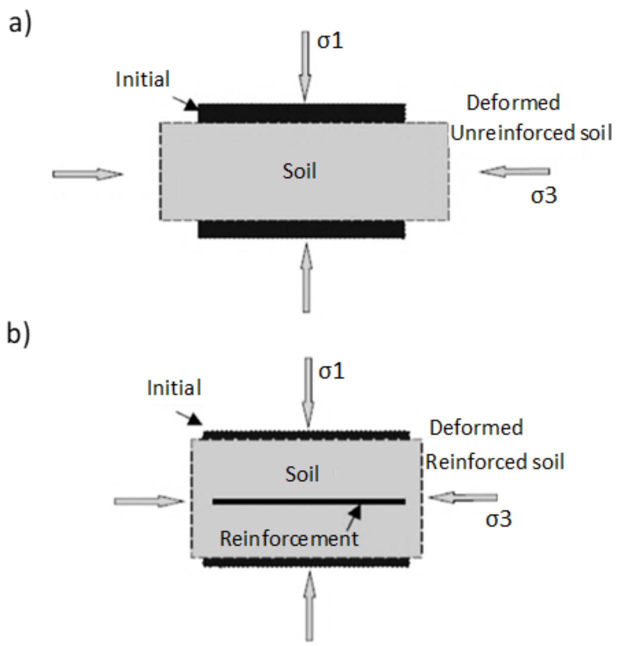

Figure 3 – Influence of reinforcement a) Unreinforced soil element; b) Reinforced soil element (Borges, 2012).

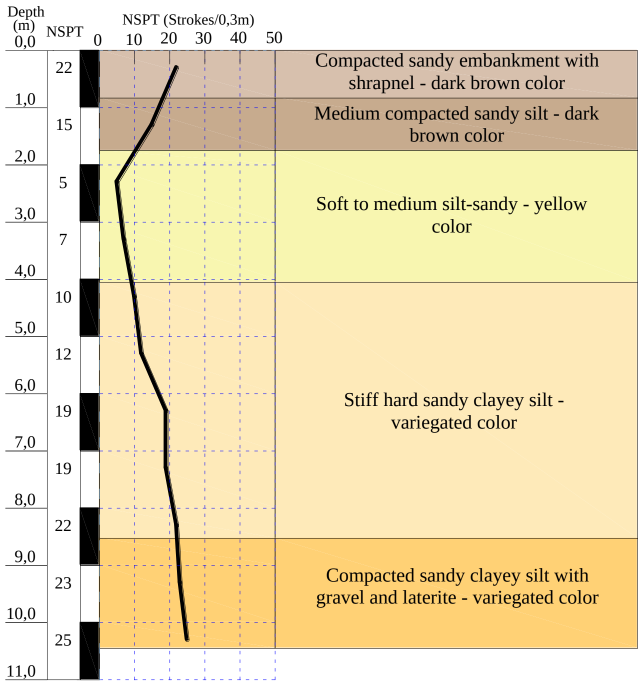

Figure 4 – SPT Probing Test Results.

2. Methodology

2.1. Soil Characterization

To determine the soil stratigraphy and the load capacity of the layers, a Standart Penetration Test (SPT) was carried out in the field. From the results obtained from the SPT test, it was verified that the most superficial layers of soil of direct foundation implantation are composed of compacted sandy soil with shrapnel to a depth of 0.83m, followed by medium compacted sandy silt up to 4.05m deep (Figure 4).

2.2. Tests for the study of load capacity

2.2.1. Soil Models

To study the application of the geogrid as a geotechnical reinforcement, two pre-defined soil models were developed. The first model is composed of soil in its natural state, the soil was excavated to a depth of 1 meter and the load test was carried out directly on the soil under these conditions (Figure 5.a). In the second model, a simulation of the reinforced soil with the use of the geogrid was performed, the soil was excavated at 1.50 m and the engulfed layers were prepared with the geogrid (Figure 5.b).

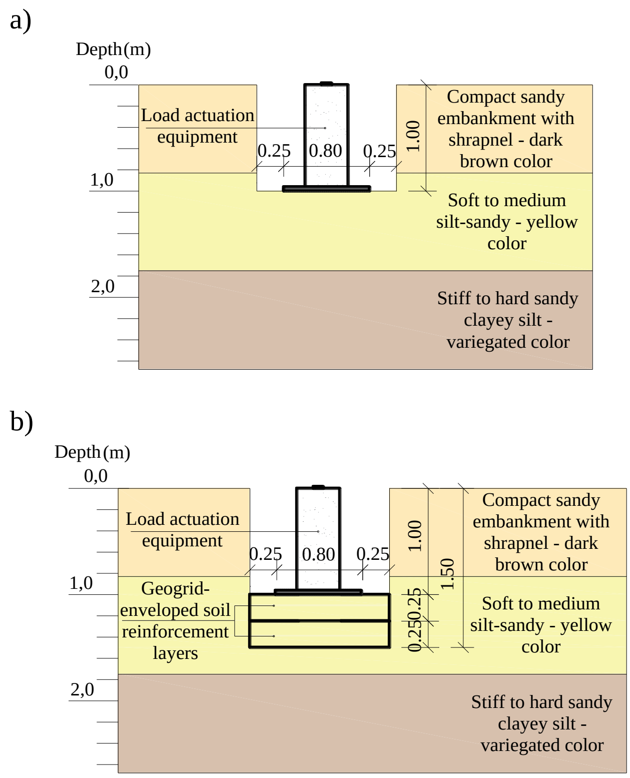

Figure 5 – Models for carrying out the load test. a) Soil in a natural state. b) Geogrid reinforced soil.

2.2.2. Assembly of the structure for the load test

For the study of the load capacity of the systems, load tests were carried out according to NBR 6489. To carry out the tests, a reaction structure was set up, which consisted of the upper bracing with two metal beams, equipped with eight sets of anchored helical piles (Figure 6). After the structure was assembled, the excavations were carried out according to the pre-defined models (Figure 7).

Figure 6 – System of reaction beams.

a) b)

Figure 7 – a) Dimension measurements b) Excavation process.

For the distribution of the applied load, the plates (with 0.80 meters in diameter and 1 inch in height) and the steel column were positioned according to the normative recommendations (Figura 8).

a) b)

Figure 8 – Positioning: a) Bottom plate and column b) Top plate and hydraulic jack.

After assembling the support structure, the load application device was implemented, a simple hydraulic jack, with a nominal load capacity of 588.4 kN and a maximum load capacity of 706.1 kN. The measuring system was also installed, composed of four strain gauges orthogonally fixed to the beams using magnetic claws (Figure 9).

a) b)

Figure 9 – a) Monometer b) Pump (helps load application).

Figure (10) shows the test structure completed after performing all the described procedures. Photos of the geogrid application in the second model are shown in Figure (11).

Figure 10 – System test structure.

Figure 11 – Geogrid Application.

2.2.3. Load Testing Process

Two rapid load tests were carried out, one for each soil model. The test began with the application of the load gradually, through 9 (nine) equal and successive stages, with an increased tension of 0.0490 kPa lasting 5 minutes each, with displacement measurements being performed at the times of 0 and 5 minutes. This fast-charging phase was started with zero charge and ended with a tension of 0.4413 kPa.

Then, the unloading phase was started, being carried out in 5 (five) successive stages of 5 minutes duration, with the necessary loads for the monitoring of the stages of 0.353, 0.2648, 0.1765, 0.0883, and 0 kPa being decreased, with measurements of shifts referring to the times of 0 and 5 minutes.

Figure 12 – Load test.

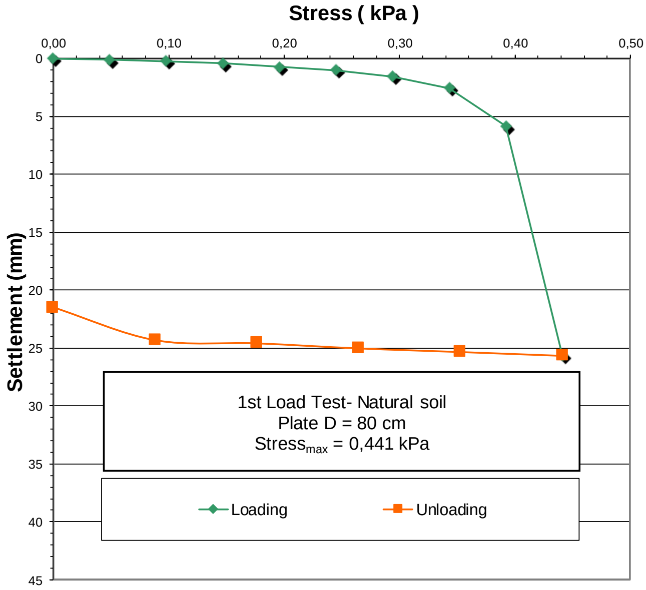

Figure 13 – Stress (kPa) x Settlement (mm) graph for natural soil.

The second test was carried out on the soil layer reinforced with the geogrid, applying an increasing load in a gradual process, carried out in 17 stages. From the results presented in the test, it was verified that the soil withstood a tension of approximately 0.844 KPa, 91.3% greater than that obtained for the soil in its natural state. In Figure (15), the load-settlement curve referring to the stages performed in the second test is shown.

3. Results and discussion

For the first soil model, a load test was carried out in order to identify the load capacity of the natural soil. From this test, the load-settlement curve was obtained, which expresses the loads applied during the test associated with the settlements suffered by the structure. From these results presented in Figure (13), it was verified that the soil withstood a tension of 0.441 kPa

From this test 25.64 millimeters of the total settlement, 21.52 millimeters of permanent settlement, and 4.12 millimeters of elastic settlement were obtained, as shown in the extrapolation graph by Van Der Veen (1953)[1] in Figure (14).

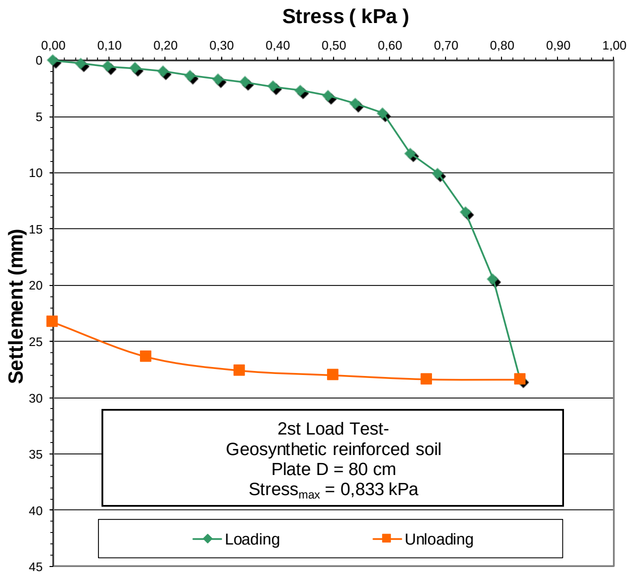

Figure 15 – Stress (kPa) x Settlement (mm) graph for reinforced soil.

1 Van der Veen's method (1953) assumes that the Stress x Pressure curve is performed from the direct load test on the plate to be represented by an exponential expression:

$$Q=Qv\cdot(1-e^{-\alpha * r})$$

Where: Qv is the vertical load applied at a given loading stage; α is a coefficient that determines the shape of the curve; r is the settlement correspondent

After the soil rupture, the unloading process was started in a decreased way, obtaining 28.41 mm of the total settlement, 23.30 mm of permanent settlement, and 5.10 mm of elastic settlement, as shown in the extrapolation's Graphic by Van Der Veen (1953) in Figure (16).

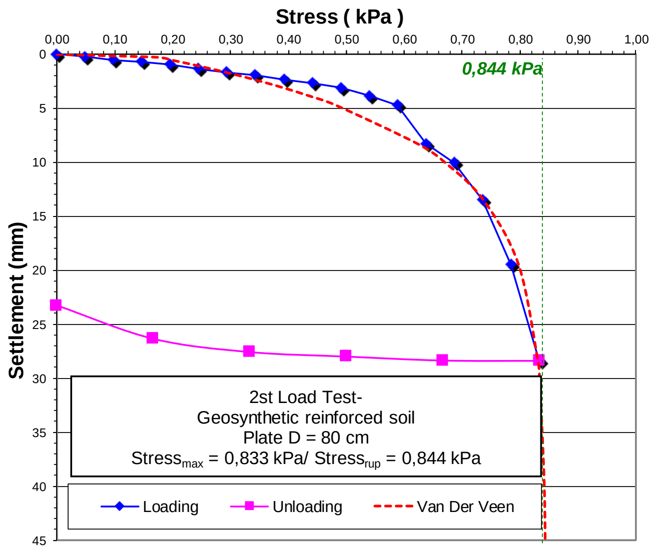

Figure 16 – Extrapolation by Van Der Veen (1953) for reinforced soil.

Regarding the strength results obtained for the soil in its natural and reinforced state, the tests showed a significant strength gain with the use of the geogrid as reinforcement.

Compared to the extrapolation graph by Van Der Veen (1953) referring to the load test in natural soil (Figure 14) with the graph referring to the load test in reinforced soil (Figure 16), in the first case, the tension obtained 0.441 kPa, while in the second case the resistance obtained was 0.844 kPa.

These results show that for the same soil and at the same test application point, the gain in the resistance provided by the geogrid was 0.403 kPa, which is equivalent to 91.38% of the resistance obtained with the natural soil.

4. Conclusion

Geosynthetics are industrially manufactured polymer materials that have various forms of use and function and that have been gaining ground in geotechnics for works on drainage systems, surface erosion control, waterproofing barriers, reinforcement, among others. Therefore, the present work evaluated the use of a welded geogrid in the reinforcement of soils for direct foundations, through the direct load test, under the recommendations of NBR 6489 and allowed the comparison of the soil in its natural

Herewith, the tests carried out demonstrated it was possible to make a preliminary analysis of the use of the geogrid as a soil reinforcement for the application of superficial foundations. Through the tests, the reinforcement of the soil with the use of the geogrid was verified, in comparison with the soil in its natural state.

From the results it was verified that the geogrid was able to strengthen the soil, increasing its bearing capacity by 91.38%. Thus, it demonstrates the possibility of using this type of solution in works with superficial foundations, on the example of soils that do not have the required strength, as long as the strength gain is sufficient for the desired application.

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