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RESEARCH ON THE SELECTION OF GEOSYNTHETICS FOR INFRASTRUCTURE WORKS

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Rezumat

Materialele geosintetice sunt utilizate la scară largă în lucrările de infrastructura transporturilor şi protecţia mediului.

Armăturile din geosintetice permit realizarea unor lucrări inginereşti dificile şi chiar imposibil de realizat, cum ar fi execuţia de terasamente pe terenuri slabe sau foarte slabe de fundare sau construcţia de lucrări de susţinere complexe.

Interacţiunea geosintetic – pământ (frecarea între feţe şi/sau caracteristicile de încleştare) reprezintă un element cheie ce joacă un rol important în cazul structurilor din pământ armat sau în alte aplicaţii unde este importantă rezistenţa materialului geosintetic la alunecare sau smulgere.

De asemenea, fluajul sub acţiunea încărcărilor de lungă durată reprezintă una dintre cele mai importante proprietăţi a materialelor geosintetice utilizate ca armături. Încercarea la fluaj permite stabilirea duratei de exploatare a lucrărilor care înglobează materiale geosintetice.

Încercările efectuate pe materialele geosintetice trebuie să fie în conformitate cu cerinţele unei anumite aplicaţii practice şi să aibă ca scop comun alegerea celei mai potrivite soluţii. De exemplu, în cazul unei lucrări de armare a unui masiv de pământ, este necesară atât cunoaşterea caracteristicilor de tip efort – deformaţie ale materialului geosintetic utilizat, cât şi determinarea parametrilor de interacţiune pământ-material geosintetic.

În lucrare se prezintă încercările de performanţă efectuate pentru ansamblul pământ-geogrilă în cadrul acestui studiu, precum şi rezultatele obţinute şi concluzii privind utilizarea geogrilelor în cadrul lucrărilor de îmbunătăţire a caracteristicilor pământului. Este evidenţiat rolul unei selecţii corecte a materialului geosintetic care urmează a fi utilizat pentru lucrări de pământ armat.

Cuvinte cheie: geosintetice, infrastructură, armare, selecţie, performanţă

Abstract

Geosynthetics are used on a large scale in transport infrastructure and environmental protection works.

Geosynthetic reinforcements allow the achievement of difficult or even impossible engineering works, such as the execution of embankments on weak or very weak foundation ground, or the construction of complex retaining works.

The geosynthetic – soil interaction (friction between surfaces and/or clenching features) is a key element that plays an important role for reinforced soil structures or other applications where the geosynthetic's strength to sliding or pull-out force is very important.

Also, the creep under long term loads represents one of the most important properties of the geosynthetics used as reinforcements. Creep testing allows to determine the service life of works that include geosynthetics.

The tests performed on geosynthetics must comply with the requirements of a certain practical application and must have as a common goal choosing the right solution. For example, it is necessary to know the strain-stress characteristics of the geosynthetic used in a soil reinforcement work, as well as the soil-geosynthetic interaction parameters.

The paper presents the performance tests carried out in this study for the soil-geogrid system and also the results and conclusions obtained on the use of geogrids in soil improvement works. It is highlighted the role of an adequate selection of the geosynthetics to be used for soil reinforcement works.

Keywords: geosynthetics, infrastructure, reinforcement, selection, performance

1. INTRODUCTION

In general, the technical terminology describes the term "geosynthetic" as a generic term for the identification and description of a product with at least one component of synthetic or polymeric nature such as a film, a tape or a three-dimensional structure, used in contact with soil and/or other materials in geotechnical or civil engineering applications [1].

Geosynthetics are commercially available in a wide range under different names and/or product types. They are versatile in use, adaptable to many situations and can be combined with several building materials.

Geogrids are used in civil engineering works to ensure the mechanical function of reinforcement. This function is fulfilled in the following representative engineering works from the transport infrastructure field:

- retaining works;
- improving the bearing capacity of the foundation soil by reducing the deformability;
- reinforcing the roads' superstructure with flexible pavement (asphalt);
- reinforcement and improvement of railway embankment superstructure.

2. EVALUATION OF THE COMPATIBILITY PROPERTIES BETWEEN SOIL AND GEOGRIDS

2.1. The reinforcement function of geosynthetics

Reinforcing the soil structures with geosynthetics leads to a global improvement of the mechanical properties of soil. This is due to the tensile and shear strengths, which govern the soil failure by expanding the plastic areas. The reinforcement elements of geosynthetics (geogrids or geotextiles) are flexible in nature and can take axial loads generated during operation. This reduces the risk of soil shearing by increasing the normal stress σ_n on the potential shearing surfaces. Figure 1 shows a schematic failure diagram of a soil structure reinforced with geogrids.

The geosynthetic's function is to mobilize frictional forces between it and soil in order to prevent the lateral sliding of soil under the action of its own weight and of an overload. The tests carried out on geosynthetics should be in accordance with the requirements of a certain practical application and should aim to choosing the right solutions. For example, in order to reinforce a soil structure, it is necessary to know the stress-strain characteristics of the geosynthetic used, and also the interaction parameters of the soil-geosynthetic system.

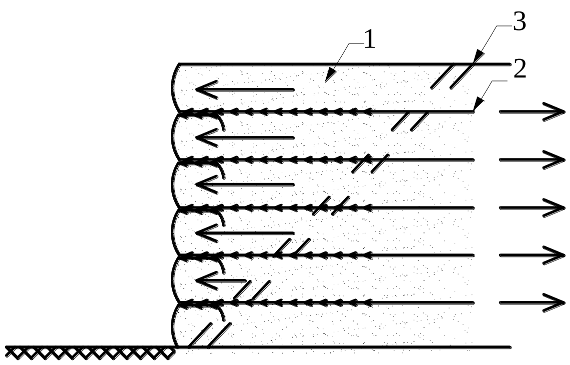

Figure 1. Pull-out failure of a reinforced soil structure, where: 1- compacted non-cohesive soil (sand and gravel), 2-anchorage length of the geosynthetic, 3-failure plan of the soil-geosynthetic ensemble

2.2. Direct shear strength

The need to determine the internal stability of an embankment is essential, as part of routine analysis procedures. When a geosynthetic is used as reinforcement, it is very important that the connection between soil and geosynthetic to be mobilized in order to prevent the soil from sliding over the geosynthetic or the geosynthetic to be pulled-out of the soil when it is subjected to traction efforts. The link between geosynthetic and soil depends on the stresses generated by the interaction at the contact surface.

The geosynthetic - soil interaction (friction and/or embedding features) is a key element which plays an important role for reinforced soil structures or other applications where the sliding or pull-out strength of the geosynthetic is important. This link between the geosynthetic and soil is mainly responsible for the stress transfer from the soil to the geosynthetic.

The paper presents some performance tests made in order to assess the compatibility between soil and geosynthetic. They were made by putting the geosynthetic in contact with soil under standardized conditions in the laboratory to simulate better the actual conditions from the field. Thus, specific properties of the geosynthetic-soil interaction can be obtained, which can be used in the design work. The shear strength developed between the geosynthetic and soil was obtained by using a direct shear apparatus with large box, of 30x30 cm. The geosynthetic sample is anchored along the edge of the box, in the area of application of the frictional force. A horizontal shear force is applied on the upper box, by imposing a constant displacement speed. The direct shear scheme is shown in figure 2.

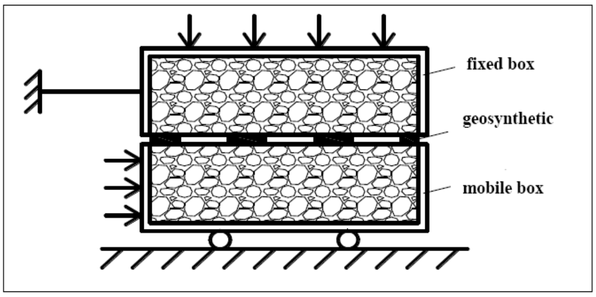

Figure 2. Scheme of the device used for the direct shear test

2.3. Creep strength

Creep under long-term loading action is one of the most important properties of geosynthetics used as reinforcements.

Given that the polymeric materials undergo elongation under tensile stresses while continuously variable in time, it is necessary to know the creep behavior of these materials.

Creep tests are performed by applying a tensile force on a geosynthetic sample for a long period of time at a constant temperature, and recording the lengthening of the material at certain time intervals. The test results are expressed as typical creep curves, which highlight the variation of the specific strain ε (%) with time.

The findings of this test are useful in designing the infrastructure and superstructure for passageways, allowing to establish the service life of works incorporating geosynthetic materials. For example, the embankments on weak foundation ground have a lifespan of 5 to 20 years, and the embankments on natural steep slopes may reach up to 100 years [2].

3. DIRECT SHEAR TESTING

3.1. Materials properties

Direct shear and creep tests were carried out by putting a geogrid in contact with a granular material in the form of a gravel with $U_n = d_{60}/d_{10} = 34.78$ (if $U_n > 15$, the soil has an uneven grain size).

A tensile test was performed in order to characterize the tensile properties of the geogrid used according to [3], using the apparatus shown in figure 3.

The tests were conducted for 6 traction elements (figure 4), the test speed was of 0.5 mm/min, and the stress-strain curve obtained is shown in figure 5. The test direction was transverse to the manufacturing direction of the geosynthetic.

Figure 3. Installation for the tensile testing of geosynthetics

a) b)

Figure 4. The geogrid tensile test: a) applying the tensile stress; b) breaking the sample

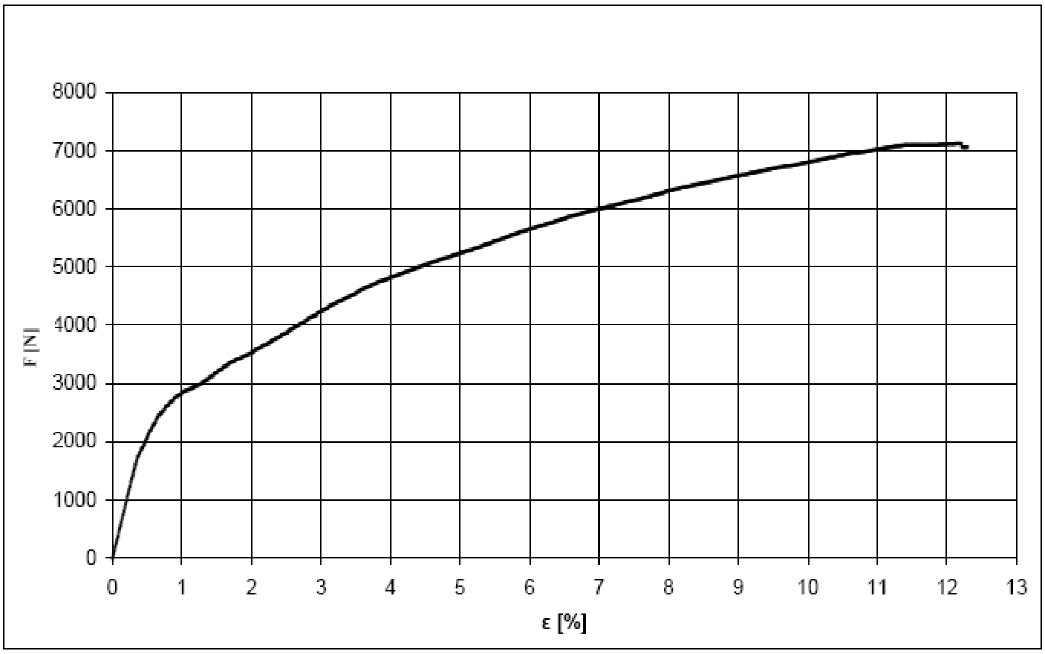

Figure 5. Strength-strain curve for the geogrid

The ultimate tensile strength of the geogrid had a value of 28.4 kN/m.

3.2. Test results and comments

For characterizing the shear strength of the granular material, a direct shear test was performed with a vertical unit effort of σ = 50 kPa and the speed of 0.5 mm/min, according to [4].

The stress-strain curve obtained in the laboratory is shown in figure 6.

In the second phase of the experiment, a direct shear test was performed by using the same device, at a normal stress of σ = 50 kPa and the speed of 0.5 mm/minute for the granular material-geogrid system.

The geogrid was fixed to the lower box frame, as shown in figure 7.

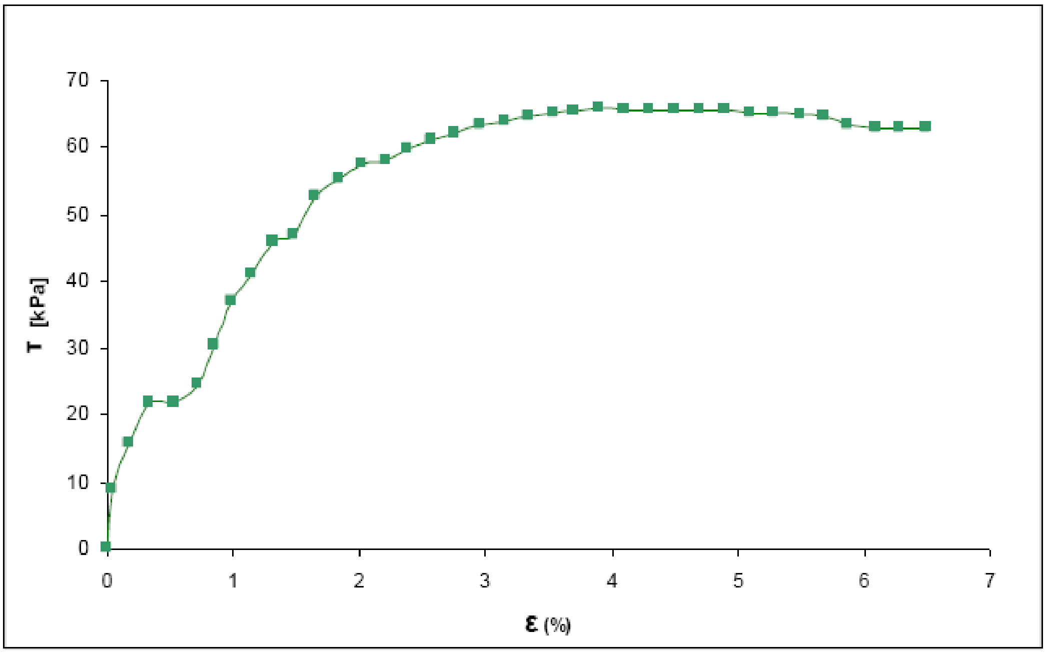

Figure 6. Stress-strain diagram of the granular material

Figure 7. Placing the geogrid in the shearing box

Figure 8 shows the stress-strain curve resulted from the test. It is noticed that for a specific elongation of $\varepsilon = 3.24\%$, a shear strength of $\tau_f = 76.90$ kPa was obtained.

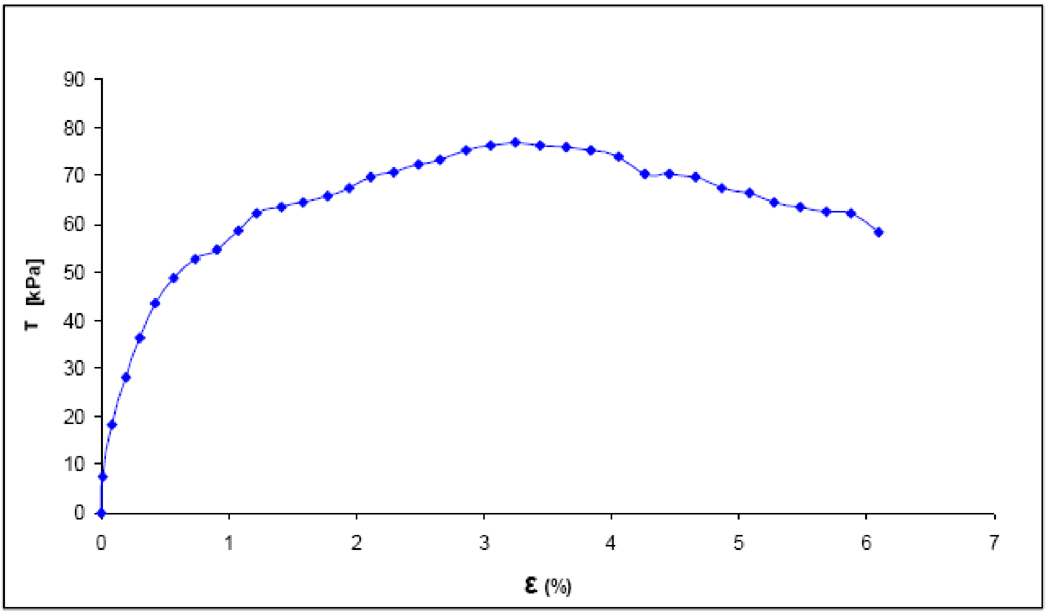

Figure 8. Stress-strain diagram for the gravel-geogrid system

For highlighting the cooperation between the granular material and the geogrid, the stress-strain curves obtained from the tensile test of the geogrid were superimposed with those obtained from the shear tests of the gravel with/without the geogrid. The resulting diagrams are shown in figure 9. The value of the tensile strength of the geogrid has been reported to the surface of the shear box, and a value of 76.04 kPa was obtained.

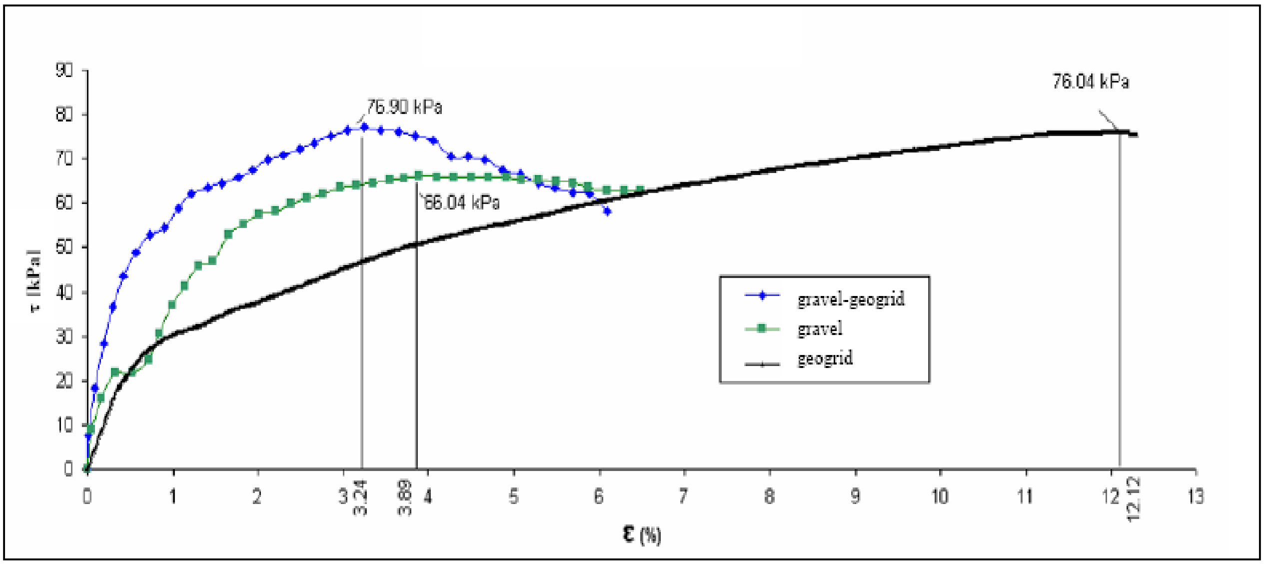

Figure 9. The superimposed stress-strain diagrams

The following conclusions can be drawn:

- for the acceptable deformation field in the engineering practice (of 2-3%), the cooperation between the geogrid and gravel (granular material) leads to an increased mobilized shear stress, with approx. 40% compared to that of the geogrid and with approx. 15% compared to that of the gravel;
- at high specific deformations (>6%), only the geogrid performs the reinforcement function, after the friction between the geogrid and the gravel dissipates due to the formation of the shear surface;
- by using the geogrid, the maximum effort, τ, increases by 16.44%, and the specific elongation at maximum shear stress is reduced by 20.06%.

The increasing unit stress quantifies the good compatibility between the geogrid and the gravel. However, the decrease in elongation can be explained by preventing the deformation of the geogrid by gripping it to the whole width of the frame of the lower box. For this reason, it is proposed that the gripping should be made only at the front of the frame in the next tests.

4. CREEP STRENGTH TEST

4.1. Materials properties

The creep test was carried out by putting in contact a geogrid with a granular material in the form of an uneven gravel with $U_n = d_{60}/d_{10} = 34.78$. The properties of the two materials are presented in section 3.1.

4.2. Test results and comments

The proposed creep test was performed according to [4], after the shear tests presented in Chapter 3.

The test was performed in the direct shear apparatus with large box (30x30 cm). The geogrid was fixed to the frame of the lower box (the mobile box), and each box was filled with the granular material having the properties presented in section 4.1. A normal stress σ = 50 kPa was applied.

The test was conducted over a period of one month, and different weights were used for imposing the shear stress. The loading was made gradually in several days. The evolution of the displacements in time depending on the applied stress is shown in figure 10.

The creep test was performed without taking into account the confinement effect given by the contact with soil. So far, several methods for creep testing taking into account the soil-geosynthetic interaction have been proposed, but haven't been yet standardized.

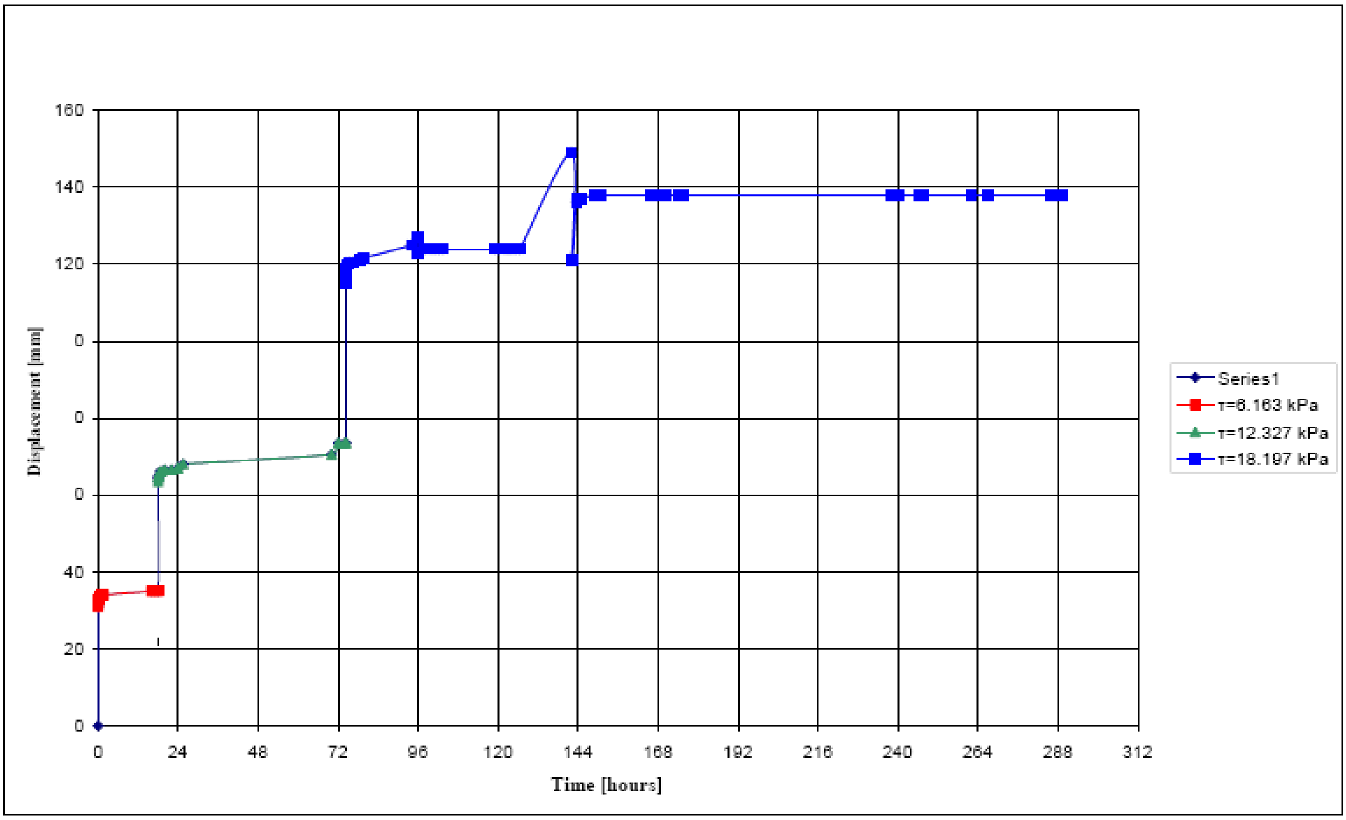

Figure 10. Evolution of the displacements in time for the soil-geogrid system

Figure 10 shows the increase in the displacement of the boxes during the first hours after applying the shear stress. For this reason, several load stages have been applied, of approximately 6, 12, and 18 kPa.

These tensile stresses are low, of about (8, 16, 23.6)%, compared to the maximum stress of 76.9 kPa.

For polypropylene, the safety factor at creep is 4. Therefore, in order to study the creep behavior of this material it should be possible to impose uniform shear stresses higher than 25% of the maximum stress. Unfortunately, the shear device reached the maximum load capacity (figure 11). For this it is proposed to redo the test at a lower overload.

Figure 11. Maximum overload of the shear device

5. CONCLUSIONS

In order to achieve maximum efficiency in the use of geosynthetics and taking into account the multiple functions fulfilled by these materials within engineering works, the selection methodology becomes very complex.

The first and most important element of this methodology is the knowledge of the meaning and values of the most important parameters of behavior directly related to the functions of geosynthetics. The correct determination of these parameters requires the use of modern equipment with which the actual conditions from the engineering works may be simulated.

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