In isolation cyclic load-extension behaviour of a geocomposite

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ABSTRACT: This work describes some cyclic load-extension tests performed on a geocomposite used as reinforcement material. The cyclic tests are load controlled, divided in two categories: constant strain rate unload-reload tests and constant load rate unload-reload tests. The tests with constant strain rate were performed with five load amplitude of unload-reload cycles. In the constant load rate tests, ten unload-reload cycles with constant amplitude and different load frequencies are imposed. The load-strain behaviour of the geocomposite was characterised using the unload and the reload stiffness, the plastic strain, the cumulated strain and the damping ratio. This study pointed out that the damping ratio of the geocomposite tends to decrease, while the stiffness tends to increase, with the number of loading cycles. For the analysed range of load frequencies, the unload and the reload stiffness are not very sensitive to the frequency. The damping ratio tends to decrease with frequency of loading. The specimens previously subjected to cyclic loading did not show significant reduction of the tensile strength when monotonically tested.

1 INTRODUCTION

Geosynthetic reinforced soil structures are being used in a wide range of applications such as retaining structures and infrastructures. These structures are subjected to various loading conditions including repeated or cyclic loads. To better understand the performance of the reinforced soil mass under repeated loading, it is necessary to investigate the geosynthetic response to simple cyclic loading conditions in the laboratory.

Commonly the geosynthetic properties used on seismic design of reinforced soil structures are also based on results of monotonic load-extension tests or creep tests. According to several authors (Rowe & Ho 1986; Bathurst & Cai 1994; Kongkitkul et al. 2004) the tensile strength and axial stiffness of polymeric materials are sensitive to strain rate, so it should be expected that the behaviour of these materials under repeated loads could be more complex.

The standard tests used typically for load-extension geosynthetics characterization do not describe the non-linear behaviour of theses materials under cyclic loading conditions. Thus, it is important to develop research programs to characterize the cyclic behaviour of geosynthetics and to implement on numerical codes suitable hysteretic models.

2 EXPERIMENTAL TESTING PROGRAM

The experimental testing program was performed on a geocomposite reinforcement consisting of polypropylene continuous filament nonwoven and high strength polyester yarns, with nominal strength of 50 kN/m.

The test specimens were cut with the dimensions defined in the European Standard for wide-width tensile tests (EN ISO 10319). For each cyclic test, three specimens were used.

The performed tests are load controlled, divided in two categories: constant strain rate unload-reload tests and constant load rate unload-reload tests. In constant strain rate tests, unload-reload cycles at five pre-established load levels were performed. The constant load rate tests were carried out with a single load amplitude unload-reload cycles and different load frequencies.

The constant strain rate tests were performed with rate of strain equal to 20%/min and 2%/min. The specimens were subjected to one unload-reload cycle at 10, 20, 40, 60 and 80% of the geocomposite nominal strength.

In the constant load rate tests, the specimens were subjected to ten unload-reload cycles of constant load amplitude. Some tests were performed with amplitude equal to the maximum imposed load level (equal to 40% and 80% of the nominal strength) and other tests were carried out with amplitude equal to half of the maximum load level (40% of the nominal strength). Table 1 exhibits a summary of the constant load rate tests presented in this work.

Table 1. Summary of the constant load rate tests.

Test name	Maximum load level ($\%T_{nom}$)	Cycles amplitude ($\%T_{nom}$)	Frequency (Hz)	Cycles of loading
T80_80	80	80	0.005, 0.01, 0.02, 0.05	10
T40_40	40	40	0.005, 0.01, 0.02, 0.05	10
T40_20	40	20	0.02	10

The experimental work herein presented is a summary of a more extensive research program. Results for other tests can be found in Vieira (2008).

At the end of unload-reload cycles, all the specimens were totally unloaded and after a short period of time they were subjected to a monotonic test with strain rate equal to 20%/min.

3 TEST RESULTS

3.1 *General*

The results are presented and discussed using the values of the unload stiffness, J_{unload}, the reload stiffness, J_{reload}, the plastic strain, ε_p, the cumulated strain, ε_{cum}, and the damping ratio, D (Figure 1) for each load cycle. The strain accumulated from cyclic loading, ε_{cum}, was defined by the difference between the strain after the reload and the strain at the first unload cycle.

3.2 *Constant strain rate unload-reload tests*

Figure 2 presents the load-extension behaviour of the geocomposite under constant strain rate cyclic load tests. The cyclic load curves are compared with the mean curve of a monotonic load test. The cyclic load did not induce the strength reduction of the geocomposite. The cyclic load-extension curves come near the monotonic load-extension curve. This means that, for a given value of strain, the unload and the reload stiffness are greater than the stiffness under monotonic loading.

The evolution of the reload stiffness and damping ratio with the strain level are presented in Figure 3. The best fit lines for each value of strain rate are also plotted. The reload stiffness decreases with the strain level until a certain unload strain. For greater strain levels, J_{reload} increases linearly with the unload strain. The damping ratio has an inverse tendency. These evidences result from the shape of the load-extension curves (Figure 2).

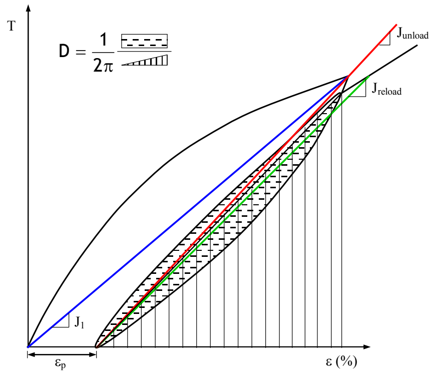

Figure 1. Definition of the parameters for the results discussion.

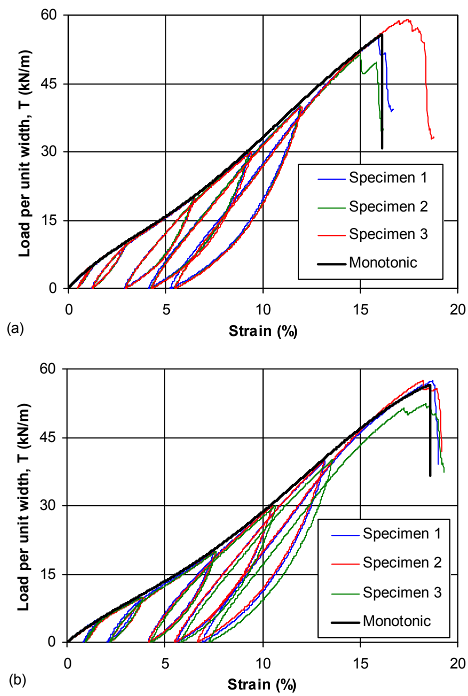

Figure 2. Load-extension curves for constant strain rate tests: (a) strain rate = 20%/min; (b) strain rate = 2%/min.

The influence of the strain rate of the cyclic loading on the reload stiffness and on the damping ratio is not very significant. The plastic and the cumulated strains increase when the strain rate decreases.

3.3 *Constant load rate unload-reload tests*

3.3.1 *Cyclic loading*

Figure 4 presents the effect of the loading frequency on the cumulated strain, on the reload stiffness normalized by the stiffness of the primary loading and on the damping ratio, for the tests T40_40 (Table 1).

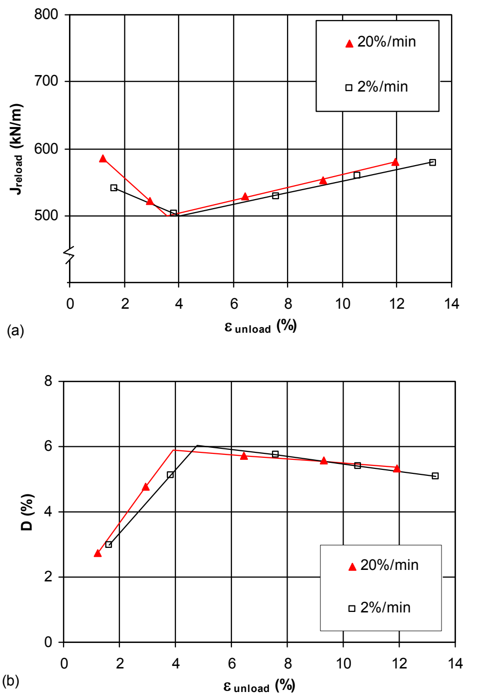

Figure 3. Effect of the strain level on: (a) reload stiffness; (b) damping ratio.

The strains accumulated from cyclic loading increase with the decrease of the cyclic loading frequency (Figure 4(a)). Although the reduced number of loading cycles, the cumulated strain seems to increase linearly with the logarithm of the number of cycles. The same effect was related by Carrubba et al. (2003) on extruded geogrids subjected to up 10000 cycles. Ling et al. (1998) consider a hyperbolic relationship more reasonable for the simulation of strain accumulated by cyclic loading of different geogrids.

The reload stiffness increases with the number of loading cycles. For the range of analysed loading frequencies, the effect of frequency is not very significant on the normalized reload stiffness, nevertheless the reload stiffness tends to increase with frequency (Figure 4(b)).

The damping ratio decreases with the number of loading cycles. The effect of loading frequency is not very expressive. Although, the damping ratio slightly decreases with loading frequency (Figure 4(c)).

Although not presented herein, the conclusions are similar for the tests performed with a maximum load level equal to 80% of the nominal strength (T80_80 –Table 1).

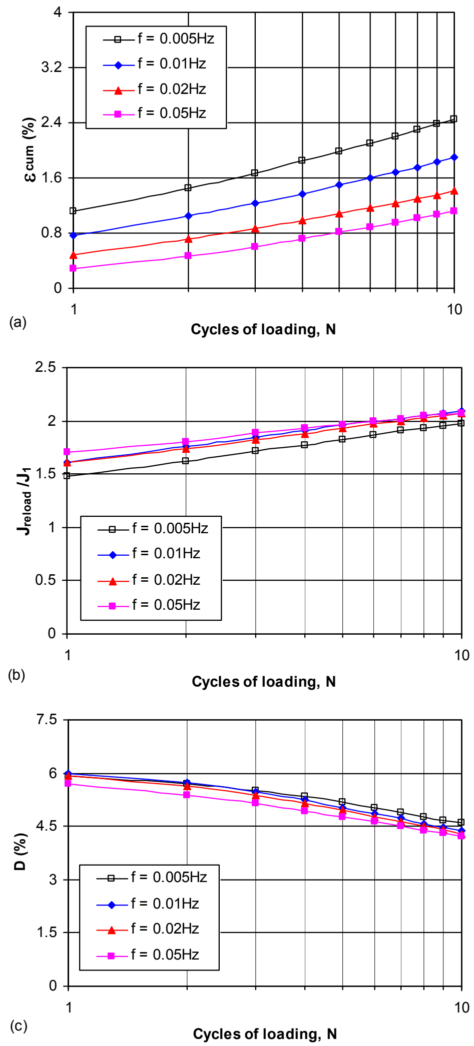

Figure 4. Effect of the loading frequency on: (a) cumulated strain, ε_{cum}; (b) normalized reload stiffness; (c) damping ratio.

Figure 5 shows the load-extension curves for two tests (T40_20 and T40_40-f = 0.01Hz), performed with the same load rate but distinct cyclic loading amplitude. For smaller load amplitudes, the unload and the reload stiffness are greater. As expected, the cumulated strain exhibits the inverse tendency.

3.3.2 *Monotonic tests*

Figure 6 presents the load-extension curves of the three specimens previously subjected to the cyclic load test T40_40-f = 0.01Hz and the mean curve of a monotonic test performed in accordance with EN ISO 10319.

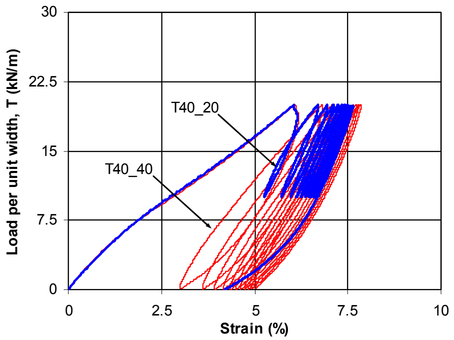

Figure 5. Effect of the amplitude of the cycles on the load-strain behaviour.

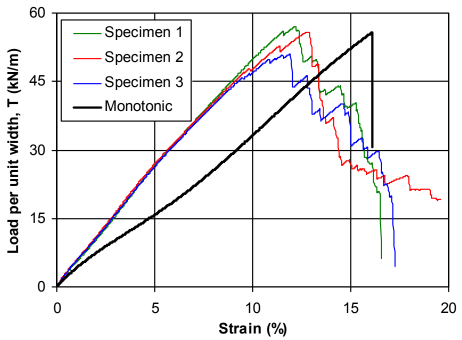

Figure 6. Effect of a previous cyclic loading on load-extension behaviour (Test T40_40 – f = 0.01Hz).

When the specimens are previously subjected to a cyclic loading, the stiffness of the geocomposite increases and, consequently, the strain at maximum load decreases. The progressive failure of the PET yarns due, possibly, to fatigue phenomena is visible.

The mean values of the maximum load reached in specimens previously subjected to a cyclic loading, T_{max}, normalized by the mean value of the maximum load achieved in intact specimens, $T_{max,monotonic}$, as a function of the mean value of the maximum strain recorded during the cyclic loading, $\varepsilon_{max,cycles}$, are presented in Figure 7. In some tests a slight loss of strength was recorded. In other tests an increase of strength was also reached.

4 CONCLUSIONS

Although the number of cycles and the range of loading frequencies were not very extensive, the experimental work herein presented allows to draw some conclusions:

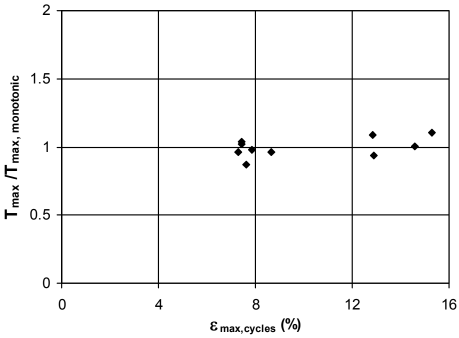

Figure 7. Effect of a previous cyclic loading on the geocomposite strength.

- the influence of the strain rate of the cyclic loading on the stiffness and on the damping ratio is not very significant; the plastic and the cumulated strains increase when the strain rate decreases.
- the damping ratio tends to decrease with the number of loading cycles and the stiffness of the geocomposite shows an inverse tendency;
- the stiffness increases and the damping ratio decreases with loading frequency;
- a previous cyclic loading does not induce a significant reduction of the geocomposite strength. In some cases, an increase of strength was recorded.

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