Installation damage and creep of geosynthetics and their combined effect - experimental analysis

M. Pinho Lopes
Department of Civil Engineering, University of Aveiro, Portugal

C. Recker
Institut für textile Bau- und Umwelttechnik GmbH, Greven, Germany

Jochen Müller-Rochholz
Department of Civil Engineering, University of Applied Sciences, Münster, Germany

M. de L. Lopes
Department of Civil Engineering, Geotechnical Division, University of Porto, Portugal

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ABSTRACT: The effects of damage during installation of geosynthetics were investigated in a research program. Damage tests according to European standards were hereby performed on various materials as well as field tests with different soils. Tensile, creep and creep rupture tests were then performed on the damaged samples and corresponding reference samples. The reduction factors for creep and damage during installation can be summarised on the basis of these results. Initial results of the European Damage Tests display very different residual strengths depending on the type of material. The evaluation of initial creep rupture tests on a PET and PP material showed changes in the summarised reduction factors of around 30% compared to former conventional methods.

1 INTRODUCTION

The combination of material testing damage during installation (DDI) and creep may open new possibilities for an increase in economic efficiency, due to a possible positive synergistic effect and a less reduced performance of damaged material under lower stresses.
To achieve a more realistic design of structures with geosynthetics, the effects of creep should be evaluated considering that it is impossible to avoid damage during the installation process of geosynthetics. Therefore it is important to assess the effect of these two combined phenomena.

The damage during installation test became standardised with the introduction of the EN ISO 10722-1 (1997) in form of an index test for laboratory simulated installation damage. In spite of the existence of this standard, field simulations similar to the ones shown by Watts and Brady (1990) and in the “Procedure for Installation Damage Test for BBA Assessments” (1997) are still necessary, due to the enormous variety of soils available under real application conditions.

2 TESTPROGRAM

The work reported in this paper aims at comparing the two test methods for DDI and to combine those with conventional creep testing. The test programme includes the following:

(a) Damage simulation in accordance to the CEN standard and by performing field test with various kinds of geosynthetics (see figure 1);

(b) Rapid loading tensile tests in accordance with ISO 10319 using damaged and undamaged specimens;

(c) Creep and creep rupture test in accordance with EN ISO 13431 using damaged and undamaged specimens.

Table 1: materials

Material No.		Nominal strength in kN/m MD/CMD
1	Woven PP-Tape (110g/m²)	22/22
2	Woven PP-Tape (210 g/m²)	40/40
3	Woven PP-Tape (320g/m²)	65/65
4	Woven PET-Geogrid	60/30
5	Woven PET-Geogrid	55/55
6	coated aramide embedded in PET-nonwoven	40/40
7	Extruded PP-Geogrid	40/40
8	PET filament core with pp sheath	50/50

3 TENSILE STRENGTH ON DAMAGED AND UNDAMAGED MATERIALS

The tests to determine the tensile strength were carried out according to EN ISO 10319 using 20 cm wide samples. Up to now, samples have been evaluated which were damaged according to the European Standard ENV 10722-1. With this test, a geosynthetic specimen is placed between two layers of a synthetic aggregate (sintered aluminium oxide) and subjected to a period of dynamic loading.

Field tests with various soil types are currently being carried out in Portugal. The results of the tensile tests on these materials will be published at a later point in time. The results available up to now are summarised in Figure 1.

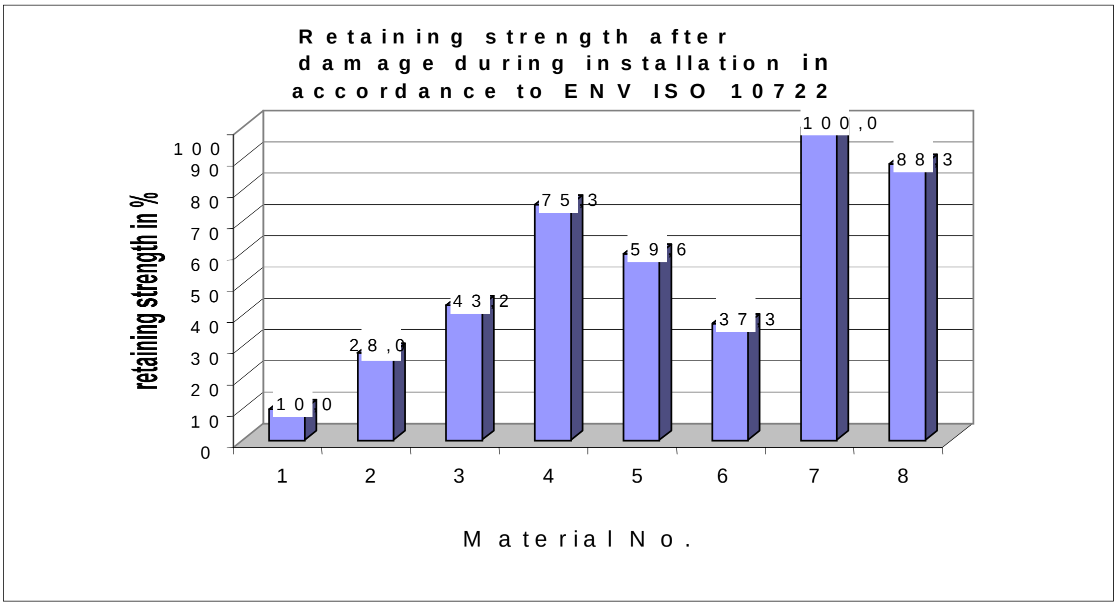

Figure 1: Comparison of tensile strength of undamaged and damaged samples

The very different residual strengths depending on the type of material are clearly noticeable. The damage caused by the sharp-edged corundum material used in the European damage tests has different effects on the materials. A PP tape fabric was damaged more seriously in this test than, for example, a woven Geogrid.

Figure 2 shows the coefficients of variation for the tensile tests.

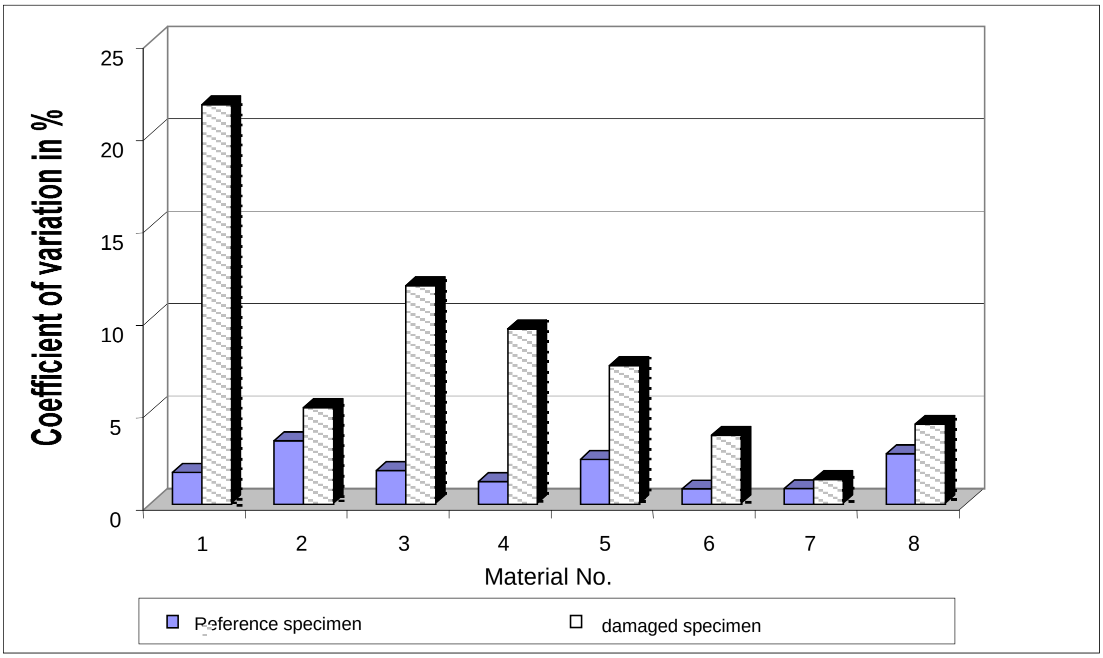

Figure 2: coefficient of variation, tensile strength

It can be seen here that the materials with the highest reduction also normally show the highest coefficient of variation. Since the test conditions were not altered in the tensile test, this means that the materials in the damage test react to different mechanisms of damaging. This can clearly be seen with the more sensitive materials. The field tests will show, whether there is similar behaviour.

4 CREEP AND CREEP RUPTURE TEST IN ACCORDANCE WITH EN ISO 13431 USING DAMAGED AND UNDAMAGED SPECIMENS

This test investigates the effects of damages on the creep behaviour. Up to now, creep rupture tests of up to approx. 100h have been carried out on three materials. The results of a woven PET-geogrid and a PP-tape have been evaluated. The tests on the other materials and longer tests (1000 h) are still going on and will be published later.

Figures 3 and 4 show the results which have been obtained to date. The creep rupture curves for the damaged and undamaged material approximate each other. Both curves would theoretically meet beyond 10^6 hours.

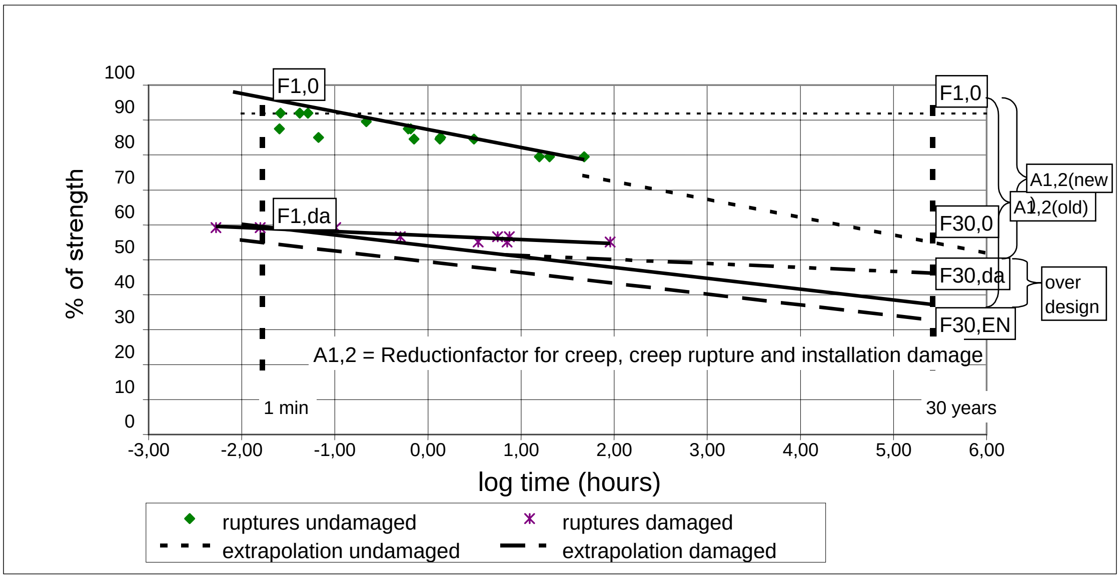

Figure 3: creep rupture plot of coated multifilament PET geogrid (55kN/m)

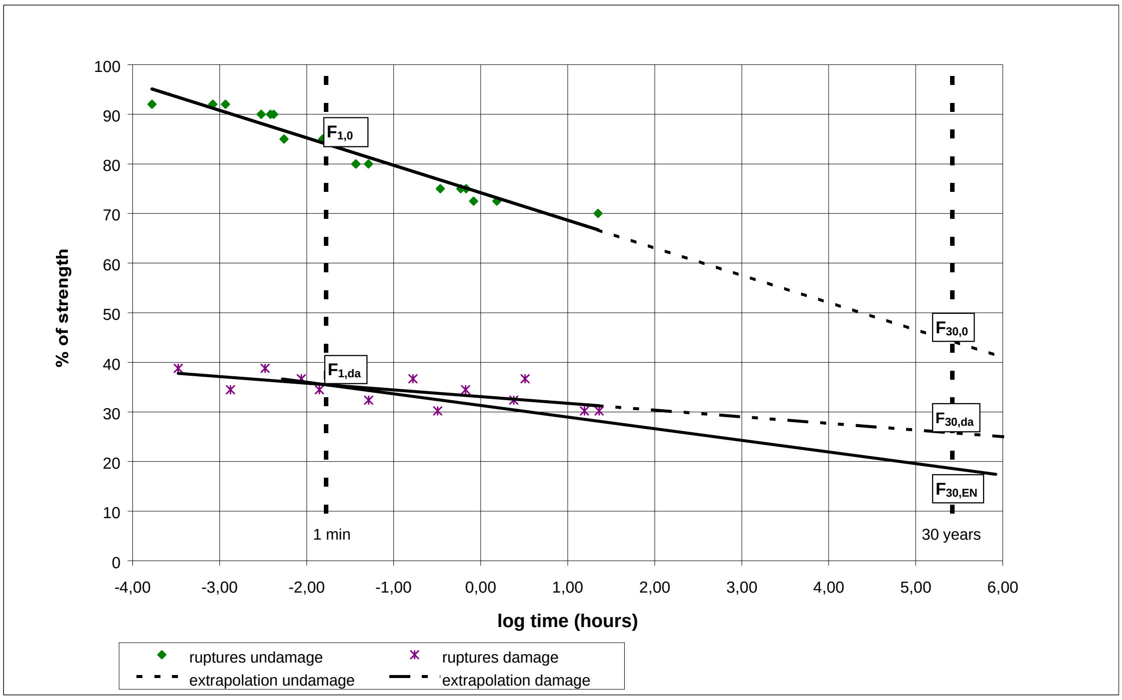

Figure 4: creep rupture plot of a woven PP-tape (65 kN/m)

Reduction factors

The European approaches are using reduction factors in exactly the referred way. For example is the following equation the basis for the design of reinforcement with geosynthetics: The design strengths of a geosynthetics is calculated by using

$$F_{Bi,d} = F_{Bi,d} = \frac{F_{Bi,k}}{\gamma_B}$$

where $F_{Bi,k}$ = the characteristic long term strength without partial safety factors; γ_B = partial safety factor

$F_{Bi,k}$ is calculated by using the following equation:

$$F_{Bi,k} = \frac{F_{bi,k,o}}{A_1 \cdot A_2 \cdot A_3 \cdot A_4}$$

Where $F_{Bi,k,0}$ = Characteristic short term strength; A_1 = Reduction factor for creep and creep rupture; A_2 = Reduction factor for installation damage; A_3 = Reduction factor for on site handling (seams, connection etc.); A_4 = Reduction factor for environmental influences (Chemical, UV etc.)

For example

The reduction factor A_1 is calculated as follows:

$$A_1 = \frac{F_{B,k,0}}{F_{B,k,1}}$$

where $F_{B,k,1}$ = permanent bearable load

The corresponding values from the two graphs, Figures 3 and 4, were determined to show the changed reduction factors. Values after 1min and 30 years were hereby evaluated. The 1 min value roughly corresponds to the value for the highest tensile strength. For test-technical reasons it is slightly lower than the maximum tensile strength determined in the test according to ISO 10319. The reduction factors A_1 and A_2 are determined as follows:

$$A_1 = \frac{F_{1,0}}{F_{30,0}} \quad \text{and} \quad A_{2EN} = \frac{F_{1,0}}{F_{1,da}}$$

where $F_{1,0}$ = tensile strength after 1 min, pristine sample; $F_{30,0}$ = tensile strength after 30 years, pristine sample; $F_{1,da}$ = tensile strength after 1 min (damaged sample); $A_{2,EN}$ = reduction factor for damage during installation (EN 10722-1 method)

$F_{30,EN}$ is calculated as follows

$$F_{30,EN} = \frac{F_{30,0}}{A_{2,EN}}$$

where $F_{30,EN}$ = tensile strength after 30 years (damaged sample)

The new approach takes the strength of the damaged sample after 30 years into account and at the same time contains the reduction factor for creep and damage during installation. The reduction factors for the first two materials are shown in table 2.

Table 2: Reduction factors, standard method and new method

Material	A_1	$A_{2,EN}$	$A_{1,2(old)}$*	$A_{1,2\ (new)}$*	overdesign in %
woven PET-geogrid (55 kN/m)	1,67	1,68	2,81	1,99	29
PP-Tape (320g/m²)	1,90	2,37	4,52	3,26	31

*$A_{1,2} = A_1 \times A_2$

5 CONCLUSION

Compared to previous standard methods, the strengths used in the calculation of reinforced soil constructions can be reduced. The values shown in Figure 6 mean an overdimensioning of the geosynthetic of around 30% in both cases.

These results still relate to a relatively short test period. If these results are confirmed by long-term tests, the costs of structures reinforced with geosynthetics can be reduced and the attractiveness of reinforced soil constructions increased. Longterm results have to validate these first results.

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