Installation damage of nonwoven polypropylene geotextiles

Endommagement pendant l'installation de géotextiles non tissés en polypropylène

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ABSTRACT

European standard ENV ISO 10722-1 specifies a test for comparative evaluation of the installation damage of geosynthetics. Tests were conducted according to ENV ISO 10722-1 on 32 nonwoven, polypropylene geotextiles with mass per unit area from 100 to 2200 g/m^2 and tensile strength from 8 to 125kN/m. The effects of number of loading cycles and aggregate hardness were also investigated. A very good correlation ($R^2 \approx 0.90$) was obtained between installation damage index values and mass per unit area of the geotextiles. The damage index values obtained for geotextiles with mass over 500g/m^2 ranged between 85% and 95% indicating very limited installation damage. The damage index values of geotextiles with mass less than 500g/m^2 ranged between 43% and 85% indicating a very strong effect of geotextile mass on installation damage. Aggregate hardness by itself may not be a good indicator of damage potential. Increasing load cycles results in increased damage potential.

RÉSUMÉ

La norme Européenne ENV ISO 10722-1 spécifie la procédure d'un essai d'évaluation comparative de l'endommagement des géosynthétiques pendant leur installation. Suivant cette norme, on a effectué des essais sur 32 géotextiles non tissés en polypropylène dont la masse varie entre 100 et 2200 g/m^2 et la résistance en traction varie entre 8 et 125kN/m. On a de plus étudié les effets d'un nombre de cycles de chargement et de la dureté des agrégats. On a trouvé une très bonne corrélation ($R^2 \approx 0.90$) entre l'indice d'endommagement pendant l'installation et la masse par unité de surface des géotextiles. L'indice d'endommagement des géotextiles ayant une masse supérieure à 500g/m^2 varie entre 85% et 95%, ce qui démontre un endommagement limité pendant leur installation. L'indice d'endommagement des géotextiles ayant une masse inférieure à 500g/m^2 varie entre 43% et 85%, ce qui démontre un effet important de la masse du géotextile sur l'endommagement dû a la procédure de l'installation. La dureté de l'agrégat par elle-même n'est pas nécessairement un bon indicateur du potentiel d'endommagement. L'accroissement des cycles de chargement conduit à une augmentation du potentiel d'endommagement.

Keywords : geotextiles, nonwoven, installation damage, laboratory testing

1 INTRODUCTION

It is generally recognized that geotextile property values, obtained by standardized laboratory testing procedures, should not be used directly in design but should be suitably reduced to account for in situ conditions. Accordingly, reduction factors are applied on the laboratory generated property values to obtain corresponding allowable values. In strength-related problems, reduction factors are introduced to account for installation damage, long-term creep effects and chemical or biological degradation. Installation damage of geotextiles has been investigated both by field and by laboratory testing. A comprehensive review of field test results by Hufenus et al. (2005) indicates that the installation damage of geotextiles depends on geotextile type, aggregate gradation and grain shape, aggregate lift thickness, compaction energy and type of compaction equipment. Due to the large number of variables affecting the results of field tests, mostly qualitative evaluations of the available information can be obtained.

European Standard ENV ISO 10722-1 specifies a test for comparative evaluation of the installation damage of geosynthetics and yields a damage index value as the ratio of a reference property value of damaged to undamaged specimens. A geosynthetic specimen is placed between two layers of synthetic aggregate (sintered aluminium oxide) each 75mm thick, with grain sizes between 5mm and 10mm and Los Angeles coefficient (abrasion resistance) of not less than 1.9. Loading is applied through a 100mm by 200mm stiff plate. Cyclic loading between 5kPa and 900kPa at a frequency of 1Hz for 200 loading cycles is applied. Information from laboratory investigations based on standard procedures (i.e. Naughton and Kempton 2002, Paula et al. 2004) is limited primarily due to the small number of geosynthetics tested per reported investigation and provides no correlations between installation damage and geosynthetic physical and/or mechanical properties.

The observations stated above, provided the impetus for the laboratory investigation reported herein. Scope of this investigation is to provide a quantitative evaluation of installation damage of nonwoven polypropylene geotextiles based on results obtained for a relatively large number of samples tested according to standard procedures. Correlations with physical and mechanical properties were attempted. The effect of aggregate hardness and number of loading cycles was evaluated.

2 MATERIALS AND PROCEDURES

An overall view of the laboratory equipment used for conducting the installation damage tests reported herein is shown in Figure 1. This loading frame was constructed in-house and allows control of the maximum pressure of the applied cyclic load as well as the frequency and the number of loading cycles. As specified by ENV ISO 10722-1, the test container was made of stainless steel, with 300mm by 300mm internal dimensions in plan, and consisted of two parts each 75mm deep. The lower part was filled with two layers of aggregate each compacted to a pressure of 200kPa for 60s.

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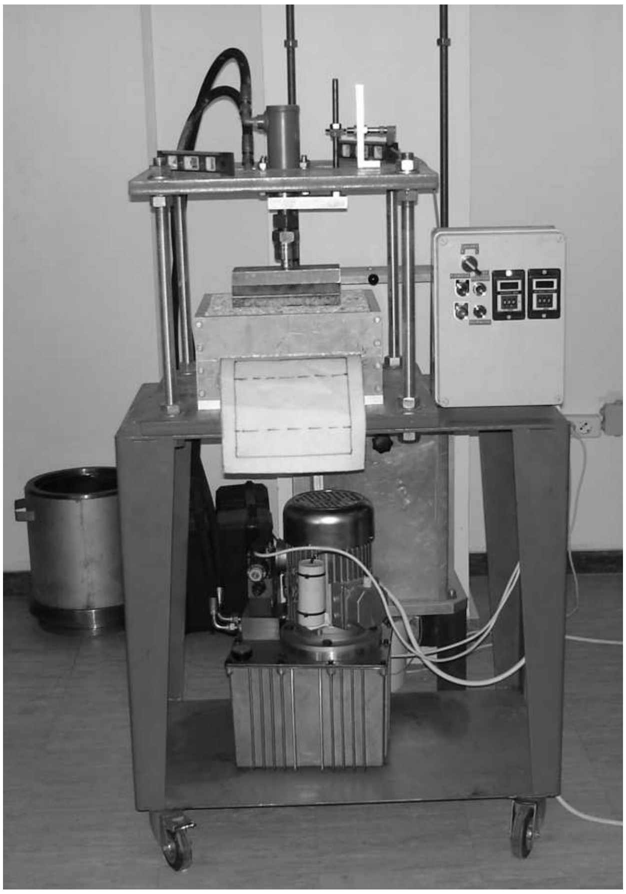

Figure 1. Laboratory equipment (ENV ISO 10722-1).

After placement of the geotextile specimen, the upper part of the container was loosely filled with aggregate. The assembled container is also, shown in Figure 1. The protruding portion of the geotextile specimen is used to obtain the reference property value for undamaged material.

For the purposes of the investigation reported herein, geotextile specimens were taken from large size samples obtained from six different manufacturers. The size of the samples ranged from 6m^2 to 10m^2 with a width equal to the standard production roll width of each manufacturer. All geotextiles were nonwoven, polypropylene, needle-punched and were made of staple fibers. One geotextile series was thermally post-treated on both surfaces. The physical and mechanical properties of the geotextiles tested covered a wide range of values. Mass per unit area (EN ISO 9864) ranged from 96.7g/m^2 to 2205g/m^2. Thickness (EN ISO 9863) ranged from 1.17mm to 11.10mm. Tensile strength (EN ISO 10319) ranged from 7.9kN/m to 75.1kN/m in the machine direction and from 7.4kN/m to 148.2kN/m in the cross-machine direction. To avoid the use of commercial names, a generic notation is used (i.e. M1) to identify manufacturer and geotextile series.

All geotextiles were tested according to the standard procedures specified by ENV ISO 10722-1. Furthermore, five geotextiles were selected as representative of the whole group and tests were conducted in order to investigate the effect of the number of loading cycles and the hardness of the aggregate. Toward this end, tests were conducted (a) with 100 and 400 loading cycles, that is with half and double the number of standard loading cycles and (b) with two more aggregates other than the standard.

The aggregate used for conducting standard tests according to ENV ISO 10722-1 was a commercially produced aluminium oxide (corundum) with angular grains and grain sizes between 5mm and 10mm. The Los Angeles coefficient of this aggregate had a value equal to 11 according to EN 1097.02. The second aggregate used was commercially produced using electric arc furnace slag and the third aggregate was crushed limestone (marble). Both had angular grains with a gradation as specified by the standard and Los Angeles coefficient equal to 16 and 26, respectively.

3 RESULTS AND OBSERVATIONS

After each test, the geotextile specimen was carefully recovered and visually inspected for damage in the form of perforations. A hole count was made and recorded. As an example of this type of damage, shown in Figure 2 is a geotextile specimen at an intermediate stage of wide-width tensile testing. In general, the number of holes decreased with increasing geotextile mass per unit area but no holes or other discontinuities were observed for geotextile specimens with mass per unit area over 300g/m^2. For light weight geotextiles with mass per unit area between 100 and 150 g/m^2, a significant number of holes was observed ranging between 10 and 20 per specimen (500 to 1000 per m^2) while for geotextiles with mass per unit area between 150 g/m^2 and 300g/m^2 the hole count ranged between 5 and 10 per specimen (250 to 500 per m^2).

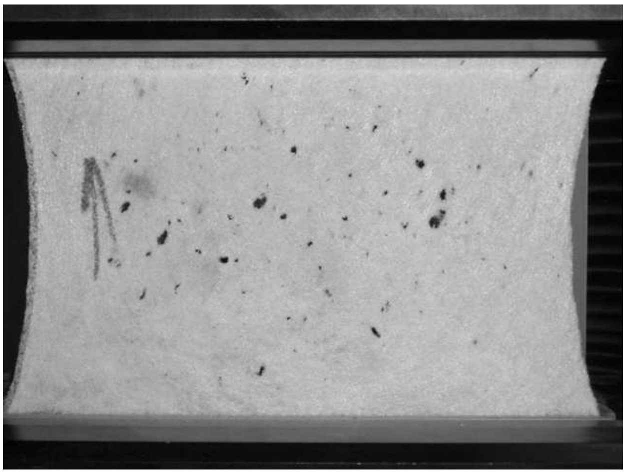

Figure 2. Damage observed as holes on geotextile specimen during tensile testing.

Installation damage was quantified on the basis of results obtained from wide-width tensile tests conducted, according to standard EN ISO 10319, on the damaged and undamaged specimens of all geotextile samples. The percent retained tensile strength and failure deformation were computed and the results are shown in Figure 3. It can be observed that geotextiles with mass per unit area of about 500g/m^2 or higher, retain a significant percentage of their tensile strength and failure deformation which ranged between 85% and 96% and between 75% and 90%, respectively. For geotextiles with mass per unit area of about 500g/m^2 or less the retained tensile strength and failure deformation decrease significantly with decreasing mass per unit area. For these geotextiles, a linear correlation between mass per unit area and retained tensile strength and failure deformation was obtained, as a first order approximation. When the damage index is expressed in terms of retained tensile strength, the correlation is very good and yields a correlation coefficient value of R^2=0,934. However, damage index values expressed in terms of failure deformation exhibit a significant scatter and are not well correlated to mass per unit area (R^2 = 0,662). These general observations were substantiated by considering separately each of the geotextile

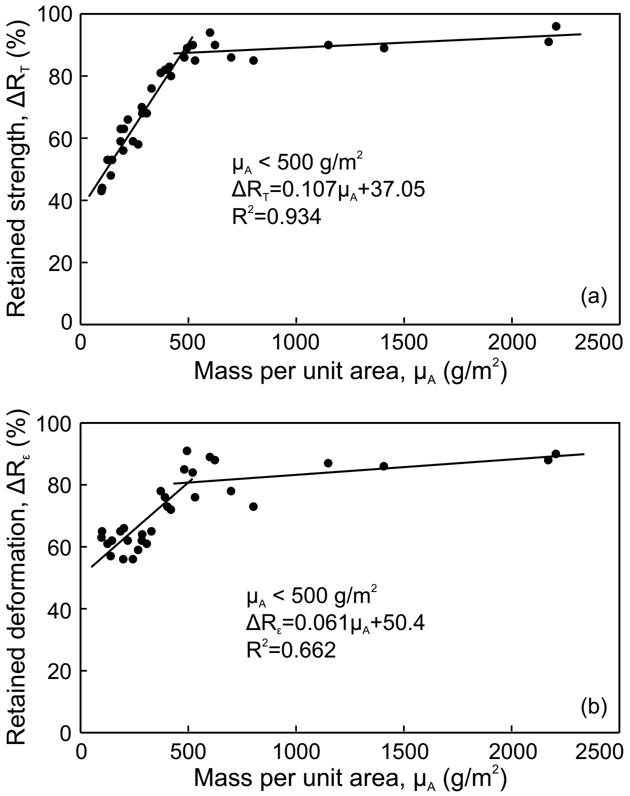

Figure 3. Correlation between geotextile mass per unit area and retained (a) tensile strength, (b) failure deformation.

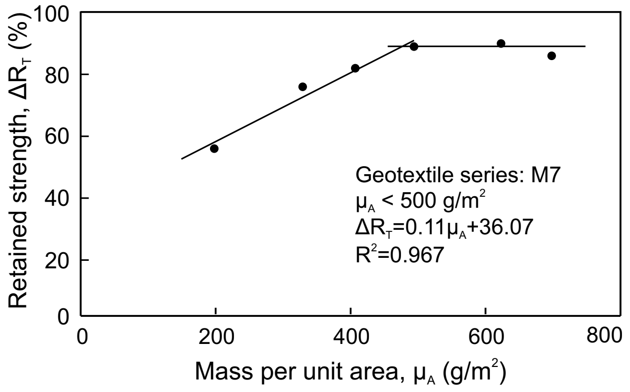

Figure 4. Typical results per geotextile series.

series tested. Presented in Figure 4 are typical results, obtained for one of the geotextile series tested, indicating that the damage of geotextile samples with mass per unit area higher than 400 to 500g/m^2 is relatively small and yields a reduction of the reference test value of not more than 10% to 20%.

Five geotextiles, representative of the whole group, were further tested in order to evaluate the effect of the number of load cycles and aggregate hardness on the induced damage. As shown in Figure 5, in terms of retained strength, the induced damage increases by increasing the number of load cycles. However, when half (100 cycles) of double (400 cycles) the standard number of load cycles (200) is applied, the effect on damage index values is not proportional. On the average, an increase of the damage index by 4% and a decrease by 7% was obtained when 100 and 400 cycles, respectively, were applied. Accordingly, the specification of 200 load cycles appears to be reasonable.

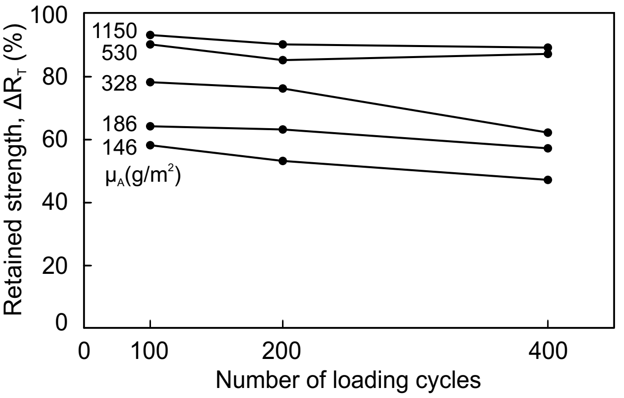

Figure 5. Effect of number of loading cycles on retained tensile strength.

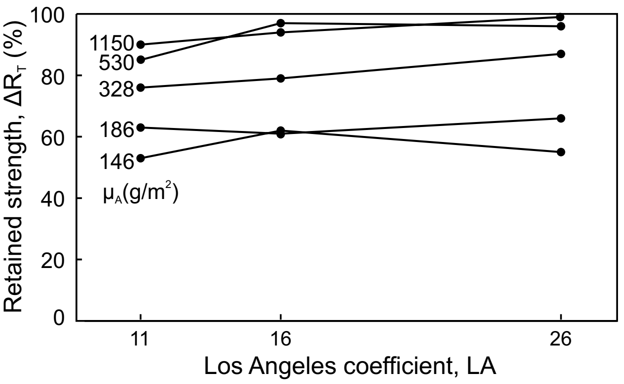

Figure 6. Effect of aggregate hardness on retained tensile strength.

Shown in Figure 6 are the results obtained when the five representative geotextile samples were tested with aggregates having different hardness values, as expressed by the Los Angeles abrasion coefficient. It can be generally observed that decreasing aggregate hardness results in increasing percentage of the retained reference properly value (reduced damage). However, it should be noticed that while the Los Angeles coefficient was increased from 11 to 16 and 26 (45% and 136% increase respectively) the resulting improvement of the damage index was, on the average, only 8% and 9%, respectively. This observation indicates that aggregate hardness by itself is not a good indicator of damage potential.

4 REDUCTION FACTORS

Installation damage strength reduction factors are recommended by Koerner (2005) for eleven different areas of application. The minimum recommended value is equal to 1.1 (1.5 for filtration/separation in railroads) and refers to applications with relatively short service lifetimes and/or cases where creep is not critical to overall performance. The maximum values recommended by Koerner (2005) range between 1.5 and 2.5 (3.0 for railroads). The FHWA (Elias 2001) recommends a range of installation reduction factors between 1.4 and 2.5 when aggregate with d_{max}<102mm and d_{50}≈30mm is used, while for finer aggregate (d_{max}<20mm and d_{50}≈0.7mm) the recommended values range between 1.1 and 1.4. Based on results of field tests on 83 nonwoven geotextiles, Hufenus et al. (2005) recommend values ranging from a minimum of 1.1 to 1.2 to a maximum of 1.8 to 2.1 depending on aggregate and compaction equipment characteristics.

The damage index values obtained for all geotextiles tested during this investigation, were used to compute the corresponding reduction factors, for damage during installation (inverse of damage index when expressed as a decimal number). For geotextiles with mass per unit area over 500g/m^2, the reduction factor values range between 1.05 and 1.20 while for geotextiles with lower mass per unit area they range between 1.20 and 2.10. It can be observed that the results obtained from the investigation reported herein are in very good agreement with the recommended values. It should be noted, however, that available recommendations do not classify or evaluate geotextiles according to their physical and/or mechanical properties and this may result in the application of similar values for the reduction factor for either light of heavy geotextiles.

5 CONCLUSIONS

Based on the results obtained and the observations made during this investigation, the following conclusions may be advanced for the installation damage of nonwoven polypropylene geotextiles:

1. The mass per unit area of the geotextiles can be used as an indicator of installation damage potential.
2. Damage index values obtained in terms of retained wide-width tensile strength are well correlated with the mass per unit area of the geotextiles.
3. The effect of installation damage is not significant for geotextiles with mass per unit area over 500g/m^2.
4. The number of load cycles specified by standard ENV ISO 10722-1 is reasonable and there is no reason for significant deviations from this number.
5. The Los Angeles coefficient value of the aggregate used to conduct the standard test is not, by itself, a good indicator of potential damage.
6. Existing recommendations provide a realistic range for installation damage reduction factors but specific values should be selected taking into account geotextile physical or mechanical properties.

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