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The Individual Properties of the Selected Types of Geosynthetics

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Abstract

The paper presents some experimental test results of the influence of selected parameters (samples shapes, short and long creep and relaxation stages, environmental degenerative processes) on the mechanical properties and behaviour of the geosynthetic materials. The individual impact of the change of the above particular parameters on the materials are investigated and some practical conclusions formulated.

Key words: geosynthetics, experimental test results, mechanical properties

1. Introduction

Over the past few decades, soil reinforcement with geosynthetics has become a very widespread and cost-effective method of improving the safety of several geotechnical structures such as slopes, embankments, foundation soils and others. The increased use of geosynthetics in civil engineering necessitated investigations and the defining of the main parameters influencing their mechanical properties. Over the past forty years, subject design procedures as well as practical knowledge in the predicting of work and behaviour of the geotechnical constructions reinforced by the geosynthetics have been extensively investigated and improved by experimental research and theoretical analyses. At present, the technical standards describe precisely the procedures and conditions (temperature, humidity) in which the physical and mechanical properties of the construction materials should be examined (Bolt, Duszyńska 2001). However, it is indicated that most of the required tests are performed in laboratory conditions, while the construction materials in practice are exposed to natural conditions, which may substantially affect the said properties. As, for example, the confining stresses normal to plain, unexpected stress-strain histories (short intermediate creep stages during the construction processes) and others are omitted. The question is: to what extent should the said problems be included in detail, in the examination, design and construction standards? In fact, to predict their influence on the long-term behaviour of geosynthetics is quite difficult, because the construction material parameters depend on the complex interaction between many factors (Van Santvoort 1994, Ingold 1994, Koerner 1987). It seams worth mentioning that currently, during standard design procedure, the characteristic tensile strength of geosynthetics are reduced by very high reduction factors only (Muller-Rochholz et al 2000), without the more detailed engineering.

In the Soil Mechanics Laboratory of the Institute of Hydro-Engineering the geosynthetic construction materials tests have been carried out for several years thus we have quite extensive practice, experience and references in this field. In this article the results of the selected sample types of these tests and examinations are presented. They show the influence of several factors on mechanical properties of geosynthetics. In specific the following parameters are considered:

- shape of samples;
- short creep or relaxation stages;
- long creep or relaxation stages;
- selected degenerative processes which were observed during field experiments.

The presented results of the experimental tests illustrate the individual effect of the changes of the particular parameters on the physical and mechanical properties of the examined materials.

It is quite important to recognise, besides knowing the general information about the geosynthetics properties, the particular conditions in which the geosynthetics materials will be used and work in the geotechnical constructions. Therefore, the examinations and testing of the geosynthetic samples should be performed in conditions as close as possible to the future field ones.

2. Brief Description of Tensile Tests

2.1. Materials

All of the tests were performed on the specimens prepared from the geosynthetics produced in Poland. Table 1 gives details of the different materials used in the experiments.

2.2. Tensile Tests Procedure

Tensile strength and elongation at failure are the basic parameters of every kind of geosynthetic. They are obtained during the unaxial tensile tests. In these the geosynthetic sample of width *B* and length *L* is clamped. During the standard

Table 1. Basic characteristics of the investigated geosynthetics

Geosynthetic (generic symbol)	Method of construction and polymer composition	Mass per unit area [g/m^2]	Tensile strength [kN/m]	Elongation at failure [%]
"Lentex" nr 48214/210/26/0 (L)	Polypropylene (PP) needle-punched geotextile reinforced with polyethylene (PE) geonet	608	19.5	8
"Watina" nr 7/14/310 (W)	Non-woven, stitched, polypropylene (PP) and polyester (PET) geotextile	220	7.4	36
"Instytut Włókiennictwa" nr I-V/400 (IW)	Non-woven, needle-punched polypropylene (PP) and polyester (PET) geotextile	400	12	120
"Pabianice" nr 41-100/1 (PT)	Woven polyamide (PA) geotextile	445	110	34
"Złoty Stok" nr 231/200 (ZS)	Polyethylene (PE HDPE) geonet	570	6	39
"Pabianice PpT" nr 156-164 (PpT)	Woven polypropylene (PP) geotextile	320	100	27

test the clamps are moved apart at a constant rate. The process is continued until the applied load reaches the maximum value when the sample breaks. The test is commonly called the wide width strip test (currently a sample's width is usually at least twice its height – PN EN ISO 10319). Formerly the experiments were performed on long, narrow samples (typically 50 mm wide and up to 200 mm long).

Geosynthetics are not isotropic materials, so on their tensile strength is measured in the two orthogonal directions:

- the machine direction (in which the geosynthetic is produced),
- the cross machine direction.

In this article the main attention is paid to geosynthetics properties, first in the above mentioned directions, in which the materials usually work in reinforced earth constructions.

Generally, the results of the tensile tests are presented graphically in the form illustrated in Figure 1.

All the tensile tests presented in this article were performed in similar laboratory conditions for the materials of the particular producers. The average room temperature was 20°C(±2°C). Average humidity in the laboratory was 57%(±8%). Sampling and preparation of test specimens were done according to technical standard PN-EN 963.

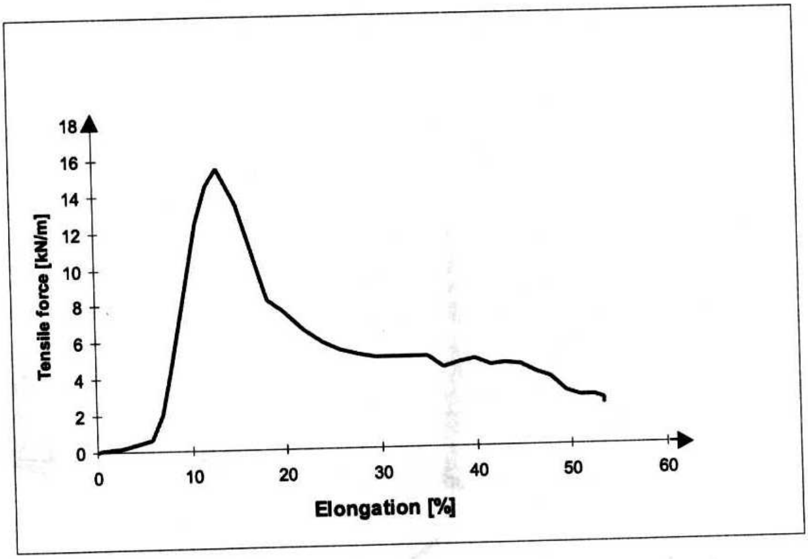

Fig. 1. Typical geosynthetic load-elongation graph (material L)

3. The Influence of Selected Factors on Tensile Tests Results

3.1. Specimen Geometry

The standard tensile tests of four different geosynthetics (L, W, PT, PpT) were performed on different shapes of samples. The following sizes of samples were used in the experiments (width × length in cm): A – 10 × 10; B – 10 × 20; C and D – 5 × 25. Samples: A, B, C were cut out in the machine direction, the samples D – in the cross machine direction. The tests of specimens C and D were executed at the Technical University of Koszalin (Filipkowski, Jacoszek 1998).

The influence of specimen geometry on ultimate strength is shown in Figure 2. The data indicates that the difference between the maximum and minimum values of the ultimate tensile forces, obtained for different shapes of geosynthetics, is between 13% (geotextile L) and 75% (materials PT and PpT).

Comparison of the elongation at the failure stage obtained for the same above mentioned specimens is shown in Figure 3. It is easy to see that the elongation depends on samples geometry – for example the average difference between value of this parameter for geosynthetics PT and PpT (types of samples: B and C) exceeds 30% .

Moreover, comparing the machine and the cross machine measurements it is visible that the experimental results directly show the anisotropic nature of all of the geosynthetics (PT, PpT, L) tested in the two orthogonal directions.

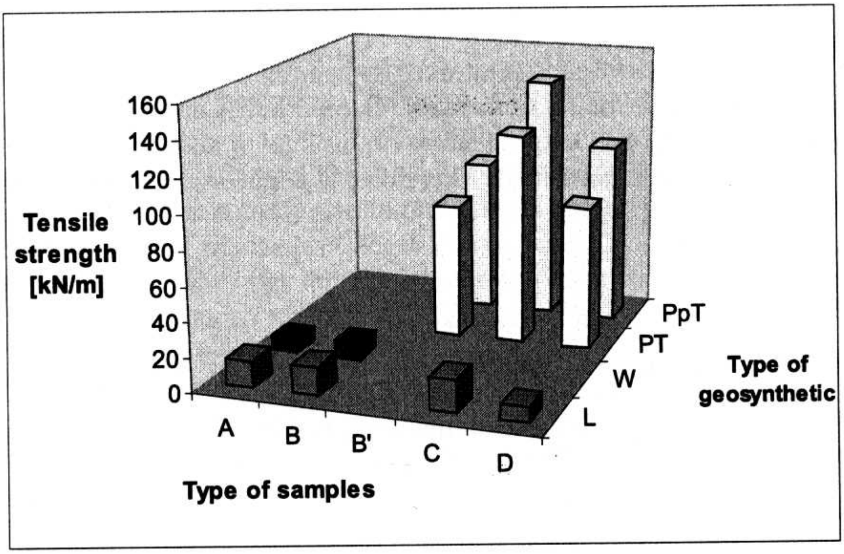

Fig. 2. The influence of geosynthetic geometry on the tensile strength

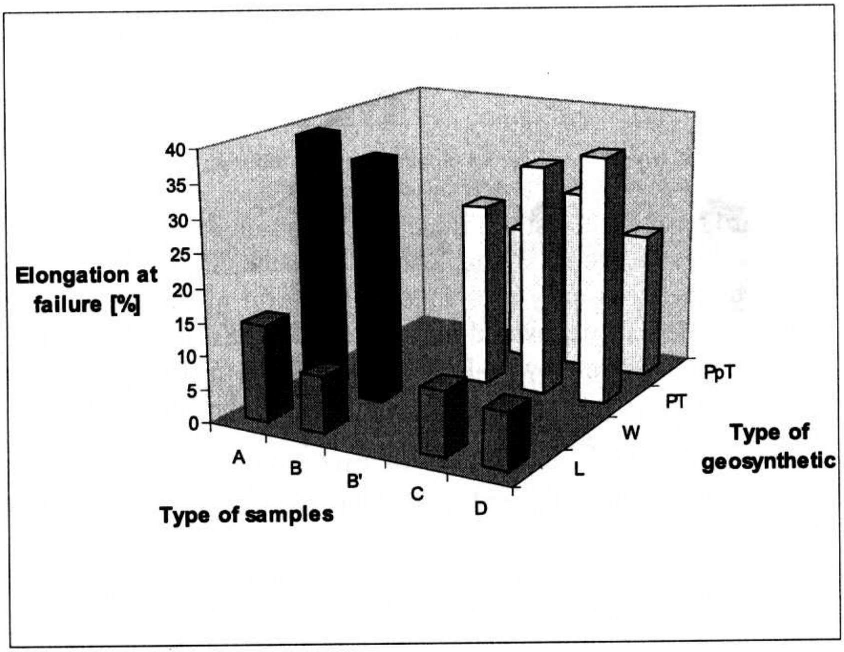

Fig. 3. The influence of geosynthetic geometry on the elongation at failure

3.2. Creep and Relaxation Stages

In order to design geosynthetic reinforced structures it is necessary to know the long-term behaviour of the reinforcement. Geosynthetics are generally produced from polymers and the well known feature of this kind of materials is the tendency to creep under the sustained load. Therefore, it is necessary to know the creep performance of geosynthetics.

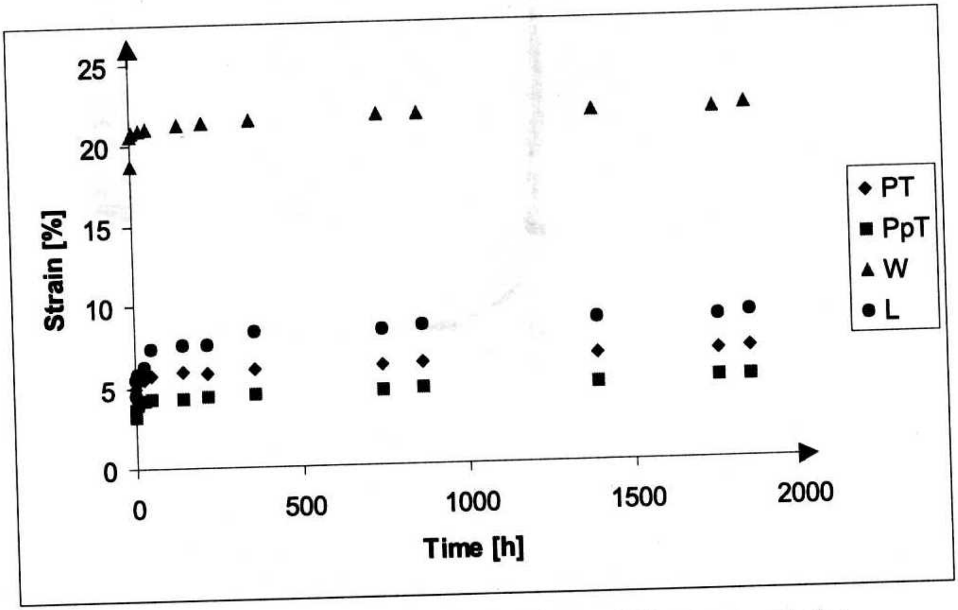

Fig. 4. The typical creep curves obtained for the different geosynthetics

The standard tensile creep strain is measured on samples being under constant load, less than the short term failure load – see technical standard PN-EN ISO 13431. Their results are usually presented in the form of the creep curves (Das 1990, Greenwood 1990, Greenwood and Myles 1986, Kabir 1988, Matichard et al 1990, Sawicki and Kazimierowicz-Frankowska 1998). In the typical creep curve (see Figure 4 – where the stress level equals 40% of the short tensile strength) the two phases can be determined:

- the primary creep stage (after loading, characterized by large but decreasing strain rates),
- the secondary stage (where, for the lower stress level, the creep curve tends to horizontal asymptotes).

During the experiments the influence of the short (1 hour) and long (200–1000 hours) term creep and relaxation tests on the geosynthetics behaviour were investigated. The main purposes of the experiments were:

- to compare the mechanical properties of geosynthetics before and after creep and relaxation stages,
- to recognise their behaviour during the above mentioned stages.

During the short term tests the specimens of geosynthetics (W, L, IW, P, ZS) were stretched with the constant strain rate up to a certain load level (in the range between 20%–80% of the short strength ultimate force), followed by short creep or relaxation stages. After this the extension at the same strain rate was continued up to failure. From one to four intermediate creep and relaxation periods were introduced during the tensile test. The stress-strain characteristics obtained during these tests were compared with standard tensile curves (without the intermediate stages). The exemplary shapes of these curves are shown in Figure 5.

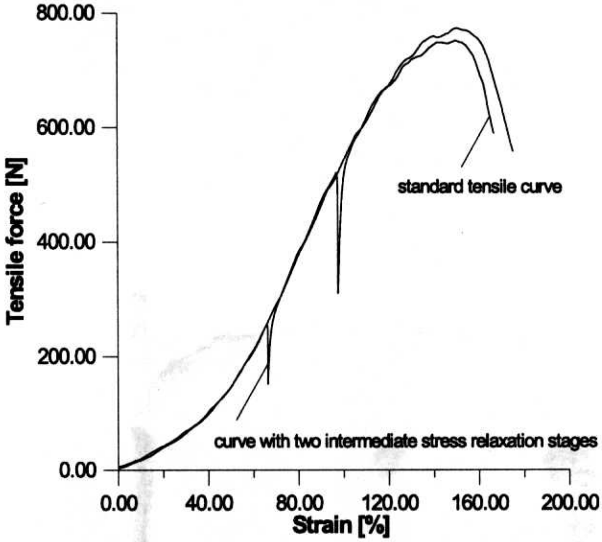

Fig. 5. The load-strain curves for geosynthetic IW

It is easy to note that the short intermediate periods of creep and relaxation stages do not influence the tensile strength of materials. After these stages rapid return to the standard stress-strain curve was observed (for all the investigated geosynthetics). Extensive experimental material from such experiments was presented in previous publications (Kazimierowicz-Frankowska 2002, Kazimierowicz-Frankowska 2003).

During the long term creep tests the value of the tensile stress was equal to 40% of the short term strength of geosynthetics. The quantitative character of the obtained creep curves was similar for all of the investigated geosynthetics (L, W, PT, PpT) – see Figure 4. After the period of 1000 hours the samples were unloaded and standard tensile tests were performed.

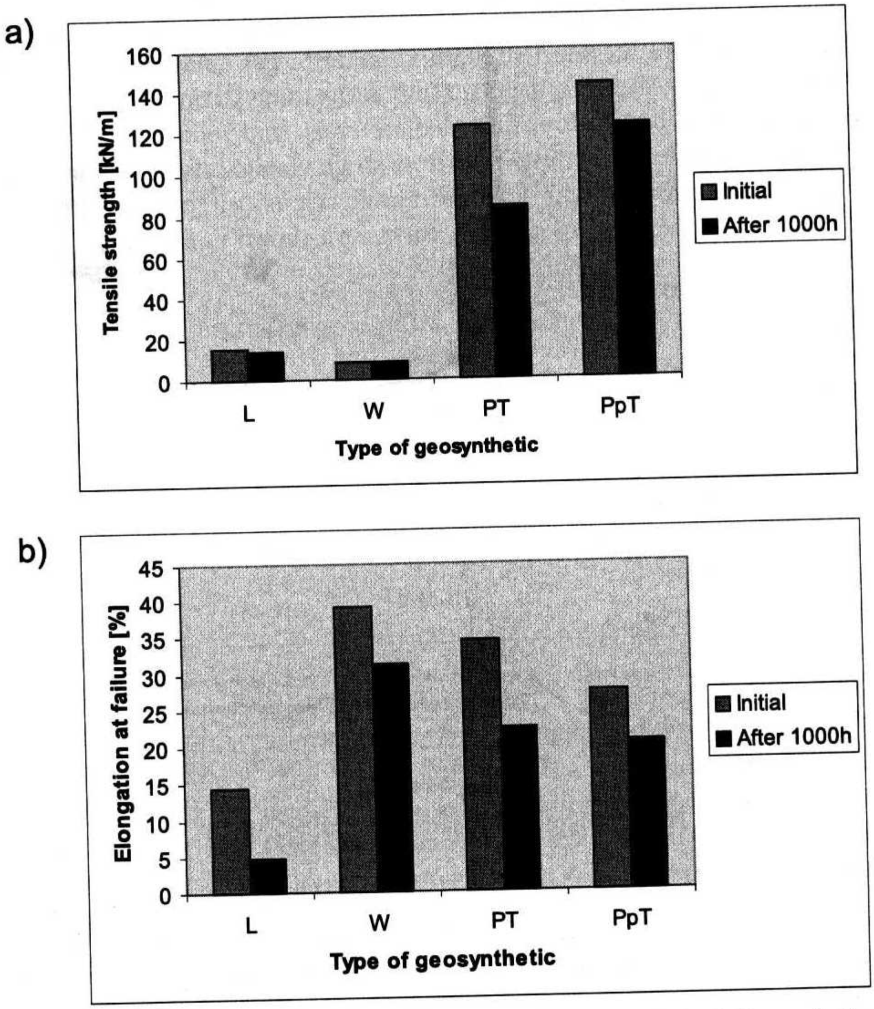

Fig. 6. The basic mechanical parameters of selected types of geosynthetics before and after long creep tests (a – tensile strength; b – elongation at failure)

The basic mechanical parameters of all the investigated materials were changed after the creep tests (see Figure 6). The results of the control testing performed on virgin specimens of geosynthetics showed a reduction of the average tensile strength of between 0.8% (for geosynthetic W) and 47% (for geosynthetic PT). An average elongation at the failure stage of virgin samples was greater, in the range of 25% (geosynthetic W) up to much more than 100% (material L) compared with the elongation measured on the samples after the long term creep tests.

The stress decrease (D) measured during the relaxation stages was proportional to the stress level (σ) at witch the stages were beginning:

$$D = A\sigma. \tag{1}$$

In the above formula, A is the coefficient which should be determined experimentally. The average values of this coefficient varied from 0.28 (geosynthetic W) to 0.47 (geonet ZS). It can be observed that the reactions of all of the materials for the first stress relaxation stages were stronger that for further stages (approximately about 10% of A). The same tendency (proportional correlation between the initial stress level and the stress decreasing) was observed during the long term (1000h) relaxation stages. The relaxation tests were performed on the samples of geosynthetics PT and PpT.

Table 2 shows the experimental records of the specimens strains during creep stages (short and long). The measured strain properties of the geosynthetics (PT, W) were constant and did not depend on the creep stress level. The deformation of geosynthetic IW was proportional to the stress level. The strain of ZS samples during the creep stages greatly increased with the increase of the tensile stress.

Table 2. Deformation during short and long creep stages

Type of geosynthetic	Short creep $t = 1$ h, two stages ($\sigma_1 = 0.35R$, $\sigma_2 = 0,7R$)	Long creep $t = 200$ h, three stages ($\sigma_1 = 0.1R$, $\sigma_2 = 0.2R$, $\sigma_3 = 0.3R$)
PT	$\varepsilon_2 \approx \varepsilon_1$	$\varepsilon_1 \approx \varepsilon_2 \approx \varepsilon_3$
W	$\varepsilon_2 \approx \varepsilon_1$	$\varepsilon_1 \approx \varepsilon_2 \approx \varepsilon_3$
IW	$\varepsilon_2 = 2\varepsilon_1$	no data
ZS	$\varepsilon_2 = 6\varepsilon_1$	no data

3.3. Long-term Material Degradation

One of the major tasks in the use of geosynthetics in practice, is to estimate the materials' durability (lifetime). Depending on the expected work conditions, particular durability tests of geosynthetics should be performed according to technical standards (EN 12224, EN 12226 and others).

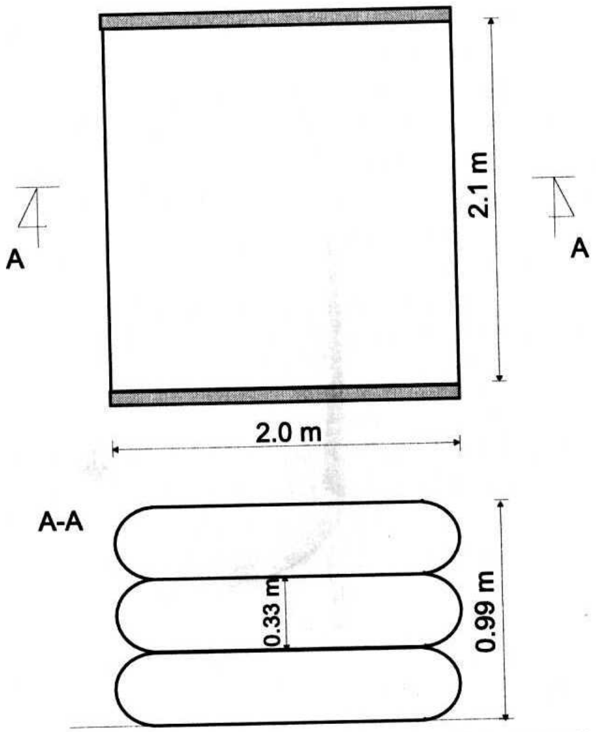

Fig. 7. Cross-section of the experimental reinforced wall

The long-term geosynthetic behaviour was tested on the samples prepared from the original material (L) previously used as reinforcement in the experimental wall (Fig. 7). The field monitoring programme was executed during the construction of the wall and later for nearly three years after. During that period, the structure was exposed to variable natural conditions (temperature, humidity). After 33 months it was dismantled and samples of the geosynthetics were taken from the different locations of the wall in order to perform the laboratory tests. The above said locations were selected in way to cover the influence of the different natural conditions, i.e. they were as follows:

- the reinforcement from inside the construction (all the time covered by the soil),
- the reinforcement strongly exposed to ultra-violet light (south side of the construction),
- the reinforcement slightly exposed to light (north side of the construction).

Degradation of the geotextile material *L* was measured basing on the percentage of the retained tensile strength with respect to its original value. The tensile tests were performed on twenty specimens from each layer of the reinforcement, as well as on the control (virgin) geotextile. All specimens (10 cm × 10 cm) were tested in machine direction. The main purpose of the laboratory tests was to evaluate their mechanical properties after exposure to different environmental conditions. A summary of the results of the tensile tests is presented in Figures 8 and 9. On comparing the results of the samples from the different locations, it can be seen that UV light is the primary factor which causes the degradation of the geotextile. The geotextile samples taken from the south side of the construction were generally in a very bad condition and the reductions of their mechanical properties were the highest (see Figures 8 and 9). The specimens taken from the north side of the wall were also in a bad condition and the results of laboratory tests show their considerable reduction of strength and elongation at failure. The basic mechanical parameters of the specimens taken from the material which were covered in the soil (the top and middle layers of the wall) were almost the same as initially. Their tensile strength did not changed whereas the average elongation at failure decreased by about 16%.

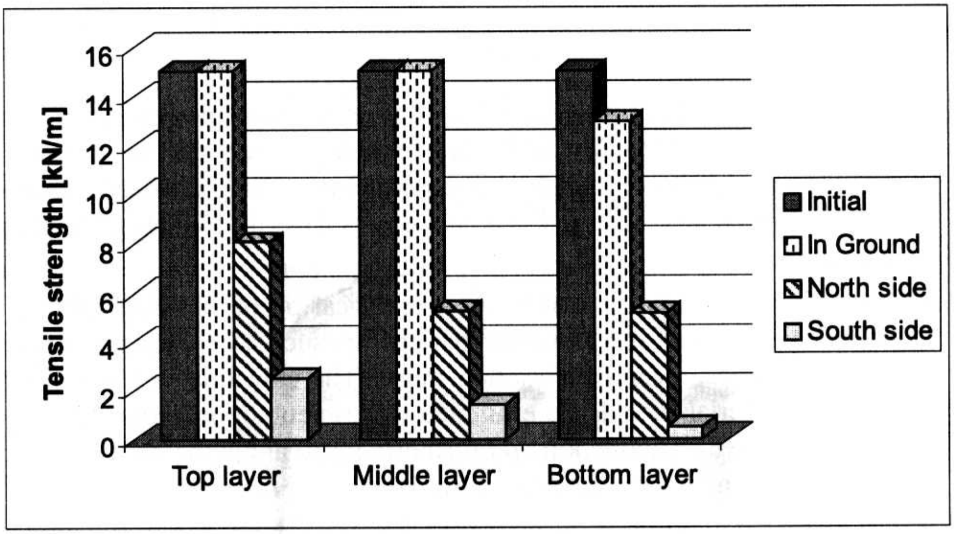

Fig. 8. Reduction of the tensile strength of geosynthetic L after 33 months of its use as reinforcement

Moreover, besides the UV light, the influence of load condition on the decrease of the reinforcement material mechanical parameters, is visible. The samples taken from the top layer of the reinforcement were stronger that those taken from the bottom layers.

4. Conclusions

Considering the results of the above-described experimental research, some practical conclusions for the engineering practice can be proposed:

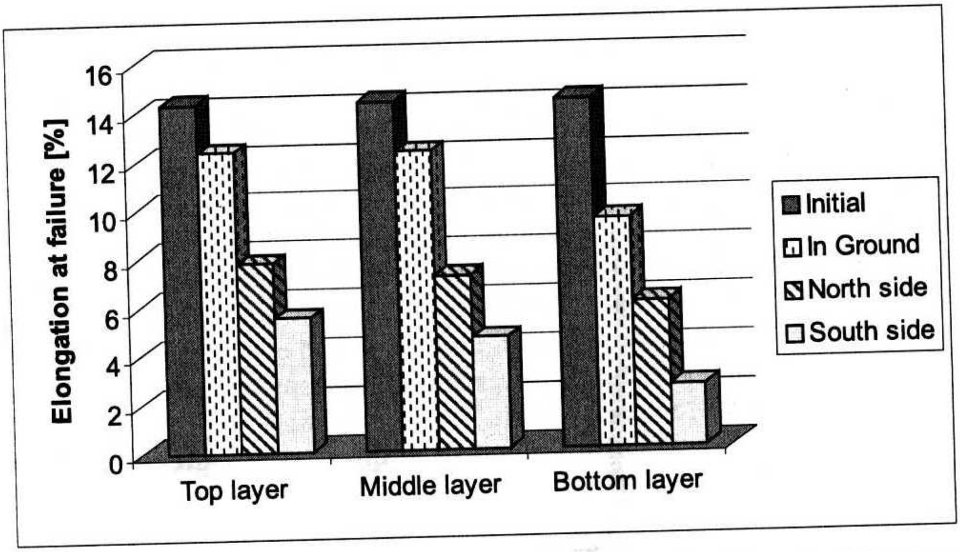

Fig. 9. Reduction of the elongation at failure of geosynthetic L after 33 months of its use as reinforcemen

- The tensile strength of geosynthetics, which is the principle design parameter for all the applications, should be determined precisely due to the fact that many factors influence its value. The laboratory testing of the geosynthetic samples should be performed in conditions as close as possible to the future field ones.
- The reduction of the geosynthetics mechanical properties depends on the individual impact of the particular parameters such as: the change of specimen dimensions, creep or relaxation stages. The individual behaviour of the different materials should be examined experimentally in order to estimate the tensile strength reduction and furthermore to apply the obtained results during the standard design procedure.
- The experimental tests of the material taken from the field experimental wall indicate the substantial negative impact of the UV light on the mechanical properties of the geosynthetic materials. The load conditions also affect the mechanical properties - the reduction is higher for the mere loaded samples. In order to assure the safe work of the real constructions they should be constantly monitored and selected samples should be periodically tested.

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