TESTING OF TENSILE PROPERTIES OF TWO NONWOVEN GEOTEXTILES

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Abstract: *The use of geosynthetics has become a common and unavoidable practice in geotechnical engineering, agriculture and environmental engineering. The main disadvantages of earthen construction materials are their insufficient tensile strength and inadequate water permeability or impermeability, depending on the problem to be solved. Such shortcomings are successfully solved by incorporating appropriate geosynthetics (geotextile, geogrid, geocells, geomembrane etc.) into earthen structures. The most used geosynthetic is geotextile, which can provide practically all functions expected from such a product. The aim of this paper was to present and analyse the relative results of multiple tensile tests performed on two nonwoven (NW) geotextiles to provide a realistic insight into the variability of their tensile properties. The obtained results showed a very similar variability of the tensile properties of the tested geotextiles.*
Keywords: *Geosynthetic, Geotextile, Variability of geotextile tensile properties, Nonwoven geotextile*

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1. INTRODUCTION

Geosynthetics are synthetic materials, indispensable in modern construction and environmental engineering, produced from artificial or natural polymers for a wide range of engineering applications. Due to the mass production their price is very low and quality is well controlled. They are most often used in geotechnical and hydrotechnical engineering, construction of roads, railways, and other infrastructure, for stabilizing terrain, building dams, embankments, for controlling or preventing erosion, in the construction of waste disposal sites and in many other areas.

When using earthen materials for the construction of engineering structures, the main disadvantage of such materials is their low or no tensile strength, and very often inadequate hydraulic permeability or impermeability depending on the technical problem we are trying to solve. Deficiencies of tensile strength and permeability of earthen materials are successfully solved by using different geosynthetics which, in combination with available earth materials, can provide economical and reliable technical solutions to various engineering problems. The most used geosynthetic, which can perform practically all functions that can be expected from such a product, is geotextile. Regarding the method of production, there are three types of geotextiles. The nonwoven (NW) type has the largest range of applications and as such is most often used.

The aim of this paper was to investigate the variability of the tensile properties of NW geotextiles, which is of course a known phenomenon, however, it should be investigated to determine its real range. According to the authors' experience obtained in testing, tolerance limits of the tensile properties for these products are often set too wide, which cannot be justified only by the very nature of these materials.

The authors presented and compared the relative results of multiple tests of tensile properties of two NW geotextiles, which according to their technical specifications are very similar, that is, according to them, it can be concluded that they belong to the same class of tensile strength. In this paper, identification marks and identification properties of the tested products are not given. Likewise, the results of tensile strength and deformation are shown only relative to the nominal values declared by the manufacturer.

Multiple tested NW geotextiles were sampled from different batches over a long period of time, from products that did not change their technical specifications in the same period, to get a realistic insight into the variability of their tensile properties.

This paper indicates that, in addition to a clear technical specification, the user also needs to have an insight into the average tensile strength values and the distribution of tensile test results in two main production directions, to be able to make an optimal decision on the compatibility of the product with his needs.

2. FUNCTIONS OF GEOSYNTHETIC MATERIALS

Geosynthetic materials can perform five basic functions:
- separation,
- soil strengthening (stabilization - improvement of load-bearing capacity and stability),
- filtering and draining,
- protection of slopes from erosion
- ensuring waterproofness (sealing) (Mulabdić & Bošnjaković 2011).

Separation implies the use of geosynthetic material between two layers of soil that differ significantly in terms of their granulometric composition, strength, and stiffness. In this way, their integrity and favourable mechanical behaviour of the separated layers is ensured.

The filtering and draining functions that can be performed by a suitable geosynthetic have different definitions. The filtering function refers to the water permeability of geosynthetics perpendicular to its surface, which we call permittivity. With the appropriate permittivity, the geosynthetic should prevent the removal of small particles (erosion) by the drag force of water percolating from the fine-grained layer into the coarse-grained material. Drainage function refers to the water permeability of geosynthetics in its plane, which we call transmissivity.

Strengthening is undertaken as a necessary measure in all situations where the soil has insufficient bearing capacity or shear strength to prevent failure and large shear deformations of the soil.

The protection against erosion caused by the action of running water and wind on the surface of the ground or slope is successfully achieved by coating the threatened surfaces with different geosynthetic products.

Sealing means the function of preventing the seepage of water with dissolved substances through permeable, porous soil layers, the permeability of which is significantly reduced by the installation of a suitable product such as a geosynthetic clay liner and/or geomembrane.

There are numerous geosynthetic products on the market today that can perform only one or more of the previously listed functions, so we distinguish: geotextiles, geogrids, geocells, geomembranes, geosynthetic clay liners…

The rapid development of geosynthetics and their good acceptance on the market are the result of:

- accelerated environmental pollution and people's growing awareness of the consequences of neglecting the environment for their health and the threat to their own survival on Earth,

- the development of science, modern technologies and new materials, and the introduction of new laws in the field of environmental protection.

The wide spread of geosynthetics is, on the one hand, a consequence of their low purchase price resulting from mass industrial production, and on the other hand, it is also a consequence of advantages that construction using geosynthetics brings compared to traditional constructions, which include only natural, earthy materials. The construction process with geosynthetics enables the application of better, safer and more durable design solutions. Construction of structures from the soil in combination with geosynthetics is much faster, more rational and efficient, and less dependent on dry weather conditions. In addition, unlike natural materials, industrial materials have factory-controlled and predictable properties that can be selected and adapted according to the needs of the engineering structure.

2.1. Geotextiles

Geotextiles are the first geosynthetic products that appeared on the market in the early 1960s. Before that, engineered textiles were mainly made from natural materials such as grass, flax, bamboo, and jute. Industrial polymers that are mainly used to produce geotextiles today are: polypropylene (PP), polyethylene (PE) and polyethylene terephthalate (PET), where PP is still the dominant polymer on the geotextile market.

We distinguish three main types of geotextiles: nonwoven (NW), woven and knitted. NW geotextiles are the most used group due to their wide range of applications. NW textiles are produced by mechanical, thermal or chemical bonding of discontinuous or continuous fibers. Depending on the type of fibers that make up the fabric, production differs in the case of using long fibers, which we call filaments, or short fibers, which are called staples (Babić et al. 1995).

So, according to the fiber type, we distinguish NW geotextiles from short fibers and geotextiles from continuous fibers. Woven geotextiles are used less often than nonwoven ones. Knitted geotextiles have very specific applications that require certain properties that cannot be met by woven or non-woven geotextiles. Furthermore, new products are appearing on the market as a combination of different materials or in combination with other geosynthetic products such as so-called multilayer composites.

A compacted soil layer can easily break up under tensile stresses (Rawal et al. 2010), if it is not reinforced by appropriate geosynthetic. A function of strengthening the soil layer with embedded geotextile is often used in geotechnical engineering (Tanasˇa et al. 2022). A sufficient tensile strength and surface friction, including appropriate stiffness, are required mechanical properties of geotextiles used for this function. The soil practically has no tensile strength or very little strength in some circumstances. The stability of the soil can be obtained with a suitable geotextile laid between its layers and the resulting composite can sustain higher loads and tensile or shear forces (Ghosh 1998). The soil, by its own friction, transfers the action of tensile forces to the geotextile. The stiffness of the geotextile should be appropriate to limit shear strains under load. If the strengthening is the primary need, then polymers used for geotextile production should be resistant to gradual changes in tensile properties due to aging, and they should not show significant creep (increase in deformation under constant load) during the entire life of the product (Tanasˇa et al. 2022; Paulson 1987).

Geotextiles produced from PP or PET materials are mainly used for the strengthening function. PET filaments have a good ratio between the strength and price of geosynthetic, and PP should not be used in acidic environments. PP is more resistant to chemical degradation, but its long-term creep characteristics are much worse than PET. In general, PET is more suitable for geotextiles that have a strengthening function, and PP for less critical applications (Tanasˇa et al. 2022).

Beside the function of separation, geotextiles have also a very important function of filtration. Geotextiles have proven to be good filters, and NW types are most often used for this purpose. A good filter ensures that so-called "particle bridges" are formed in the soil that act as an internal filter (Mulabdić & Bošnjaković 2011). For the filtration function, the geotextile must meet certain prerequisites to function as an effective filter. A good filter should allow water to pass without significant hydraulic resistance, and soil particles should be retained by it (Christopher & Fischer 1992). On the other side, retaining of small particles can cause clogging of the filter. It can be prevented if most of the pores in the filter are large enough to allow smaller soil particles to pass through (Palmeira & Trejos Galvis 2017).

3. MATERIALS AND METHODS

In this paper, only the relative results of tensile tests (in relation to the declared values) performed on two products (code names TX-1 and TX-2) of NW geotextile type are presented. The tested geotextiles were produced from mechanically connected polymer fibers that were properly stabilized to increase their resistance to the harmful effects of UV radiation. The tested products are intended for the functions of filtration and separation of various materials.

Tests of the tensile properties of the mentioned NW geotextiles were performed according to the method described in the norm EN ISO 10319 (2015), which includes testing the tensile strength on wide strips. The method is applicable to most geosynthetics, including nonwoven, woven and knitted geotextiles, geocomposites and metal products. The method can also be applied to geogrids and similar open-structured geotextiles, but the sample dimensions may need to be adjusted.

The norm (EN ISO 10319, 2015) specifies the tensile strength test method, which includes measurement of the stretching characteristics of the sample under tensile load and includes procedures for calculating secant stiffness, etc. The norm also defines special points on the curve of the relationship between stress and deformation of the sample.

Tensile tests, presented here, were performed in the test machine shown in **Figure 1**. Such tests should always be harmonized with the conditions prescribed by the international standard ISO 7500-1, that is, the test device should be calibrated in accordance with this standard. When testing the tensile strength and stretching properties of geotextiles, the test sample (**Figure 2**) is accepted by the jaws (**Figure 3**) of the testing machine, in the entire width of 200 mm. The test machine operates at a constant displacement speed, and the tensile force is applied to the test sample until it breaks. A progress of the tensile test is shown in **Figure 4**, from the start to the end of test.

Figure 1. Testing machine for tensile tests

Figure 2. A test sample of geotextile (200 mm wide strip) ready for the tensile test

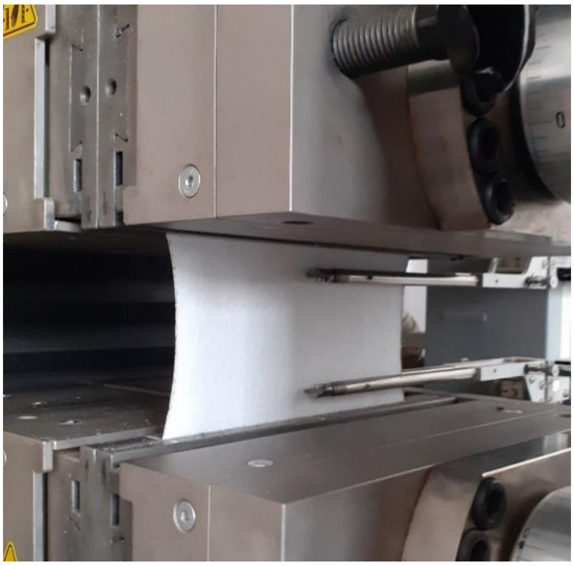
Figure 3. Jaws of the testing machine

The tensile properties of the test sample are calculated and recorded automatically by the hardware and software of the machine in real time. The speed of the test or deformation during the test is maintained within the range of (20+5) % of the initial nominal length of the sample per minute.

The main difference between this method and other methods for testing the tensile properties of materials is the width of the sample. In this method, the width is greater than the length of the specimen, because some geosynthetics under tensile load tend to shrink in the length region of the strain gauge. A larger sample width reduces the shrinkage effect of such materials. To define the relationship between stress and deformation of the sample, a suitable mechanical extensometer (**Figure 4**) is used, which monitors the displacements of two reference points on the sample. These reference points are selected on the axis of symmetry of the sample and are located at a distance of 60 mm and 30 mm on each side from the center of the sample.

During the test, the tensile load gradually increases at a constant rate. Testing of geotextiles and similar products is performed on samples with a width of at least 200 mm (**Figure 2**) or more, and the length of the sample is 100 mm, not counting the parts of the sample covered by the jaws. The test samples are oriented in the test device in two perpendicular directions, the first of which is the direction of geosynthetic production (0°, MD - machine direction), and the second is perpendicular to it (90°, CMD - cross-machine direction), i.e. placed transversely to the direction of production.

a)



b)

c)

d)

Figure 4. Progress of the geotextile tensile test: a) start of testing; b) 1/3 of tensile deformation; c) 2/3 of tensile deformation; d) end of testing
(Note: Figures 2, 3 and 4 are intended to show the tensile testing of geotextiles, and do not refer to tests on TX-1 or TX-2 products.)

4. TEST RESULTS AND ANALYSIS

NW geotextiles with code names TX-1 and TX-2, were sampled for the purpose of conducting control tests of tensile properties according to the EN ISO 10319 standard. It is important to emphasize that according to technical specifications, both products have the same nominal (absolute) tensile strength values in both main directions which are not shown here in absolute but only relative amounts as % of nominal values.

A total of 17 tensile tests were performed on the product coded TX-1 over a period of 1.5 years (**Table 1**). A total of 34 tests were performed on the product with the code designation TX-2 over a period of approximately 2 years (**Table 2**). All tensile tests were performed by orienting the geotextile samples longitudinally and transversely in relation to the direction of production. Five test samples were tested in each direction. The result of each series of 5 tests is taken as the mean value of tensile strength and the corresponding mean value of deformation. The results were statistically processed, and summaries of statistical analysis are presented in **Tables 1** and **2**.

Table 1. Summary of the statistical analysis of the test results performed on the TX-1

DESCRIPTION:	Machine direction (MD)		Cross-machine direction (CMD)		Average ((MD+CMD)/2)	
	a_f (%)	e_f (%)	a_f (%)	e_f (%)	a_f (%)	e_f (%)
Minimum value (%):	65,76	74,50	99,44	62,05	82,60	68,28
Maximum value (%):	102,24	93,46	124,08	140,75	113,16	117,11
Average value (%):	87,30	85,77	112,72	94,69	100,01	90,23
Standard deviation (%):	10,24	5,92	9,34	23,62	9,79	14,77
Coefficient of variation (%):	11,73	6,90	8,29	24,95	10,01	15,92
A total number of tensile tests: 17 nos						
Notes: 1. a_f - the proportion of tensile strength in relation to the nominal value (100%); 2. e_f - the proportion of elongation deformation in relation to the nominal value (100%).						

Table 2. Summary of the statistical analysis of the test results performed on the TX-2

DESCRIPTION:	Machine direction (MD)		Cross-machine direction (CMD)		Average ((MD+CMD)/2)	
	a_f (%)	e_f (%)	a_f (%)	e_f (%)	a_f (%)	e_f (%)
Minimum value (%):	76,80	82,20	80,80	76,31	78,80	79,25
Maximum value (%):	136,80	114,00	116,40	128,00	126,60	121,00
Average value (%):	95,51	100,78	100,14	99,95	97,82	100,36
Standard deviation (%):	12,78	6,81	9,81	14,58	11,30	10,70
Coefficient of variation (%):	13,39	6,76	9,79	14,59	11,59	10,67
A total number of tensile tests: 34 nos						
Notes: 1. a_f - the proportion of tensile strength in relation to the nominal value (100%); 2. e_f - the proportion of elongation deformation in relation to the nominal value (100%).						

Since the NW geotextiles are not used as tensile elements in soil reinforcement their tensile strength is not of primary importance. It is, however, important for the function of separation which is not to be separated from filtration function. On the level of interparticle distance, were geotextile plays a role of a bridge, the tensile strength determined from a wide strip test is not so critical, since the fibre length is closer to the pore diameter and its tensile strength is higher than on larger specimen as used in testing.

5. CONCLUSIONS

The average results of tensile strength and deformation for both tested products were in accordance with the manufacturer's declarations, i.e. within the declared range of values. A comparative analysis of the relative results of the tensile tests shows a certain difference between the tested products that cannot be observed from the declared technical specifications.

According to the presented examples (**Tables 1** and **2**), it is evident that the tensile properties of the NW type of geotextile can vary within very wide limits, where the tensile strength can be even down to 35% lower than the declared nominal value. However, such a disparity of results is not only a consequence of the variability of tensile properties due to the specific nature of geotextiles, but it is also a consequence of the relatively large freedom of the manufacturer in declaring its properties.

The results of a series of tensile tests on two products presented here actually showed a very similar variability of the tensile strength of the NW type of geotextile. From the presented results (**Tables 1** and **2**), it is obvious that the minimum value of the tensile strength is approximately 20% lower compared to the average (mean) value of the series. For this reason, it is very important for the user to know the average value of the tensile strength of the geotextile for each of the two main directions, so that he can optimally assess the suitability of the product for his needs. Unfortunately, technical specifications can often be presented in a way that does not give a clear picture of the distribution of the product's tensile properties.

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