10.2478/v10060-008-0043-0

Annals of Warsaw University of Life Sciences – SGGW
Land Reclamation No 40, 2008: 115–123
(Ann. Warsaw Univ. of Life Sci. – SGGW, Land Reclam. 40, 2008)

An analysis of physical, hydraulic and mechanic properties of nonwoven needle-punched geotextiles

DARIUSZ WOJTASIK
Department of Geotechnical Engineering, Warsaw University of Life Sciences – SGGW

Abstract: *An analysis of physical, hydraulic and mechanic properties of needle-punched nonwoven geotextiles*. This paper presents an analysis of technical parameters of needle-punched geotextiles used in engineering constructions. The tests were carried out in order to compare of physical, hydraulic and mechanic properties of needle-punched geotextiles in two different groups of products. First of group, geotextiles, were made of polypropylene fibers (PP) and the second one fabrics, were of polyester filaments (PES). The tests were performed for materials of mass per unit area 250, 400 and 600 g/m^2. The results of test showed that parameters of geotextile material depend on structure of fabrics.

Key words: polyester geotextile, polypropylene geotextile.

INTRODUCTION

Dynamic development of artificial material caused that geotextiles products are one of the popular materials used in earth building constructions. The synthetic textiles used in soils perform many functions such as: reinforcement, separation, drainage and filtration. The geotextiles are usually made from synthetic polymers: polyester and polypropylene.

Polyester: The production process and material properties are influenced by the use of various additives such as catalysts, which increase the speed of polymerization, phosphatic compounds which reduce thermal degradation during processing in the molten stage and ageing inhibitors (including carbon black) which increase the U.V.-resistance.

Polypropylene: The polymerisation of propylene monomers in the presence of specific catalyst produces the crystalline thermoplastic polypropylene. It is very susceptible to oxidation and additives are required to protect against ageing, improve thermal stabilization, UV and underwater resistance (Yeo 2008).

Geotextiles can be classified as knitted, woven and nonwoven products. The woven and knitted geotextiles are usually thin products, which technical parameters are very well-defined (Rollin 1986). In nonwoven needle-punched materials it is not easy to determine technical parameters (e.g. apparent opening size). Many methods to determine and measured parameters of nonwoven geotextiles have been used in laboratory testing programs. Unfortunately the parameters in needle-punched geotextiles are not well understood and results obtained are quite different for a designed fabric.

In this study, physical, hydraulic and mechanical parameters of needle-punched geotextiles with about the same mass per unit area, made from one producer are discussed. The main objective of this paper is the comparison of the results of technical parameters of three polyester materials and three polypropylene geotextiles.

MATERIAL

For research were used six needle-punched geotextiles made of polyester and polypropylene fibers. These materials are widely used in engineering structures. Three polyester materials (PES) and three polypropylene fabrics (PP) were used in tests. Physical, hydraulic and mechanical parameters of geotextiles (from one producer) are tabulated in Table 1.

METHODS

The methods for determining technical parameters of geotextiles material are presented in Table 2.

TABLE 1. Physical, hydraulic and mechanical properties of geotextiles

Properties	Sym-bol	Unit	Geotextiles					
			Polyester (PES)			Polypropylene (PP)		
Physical								
Mass per unit area	μ_A	[g/m^2]	250	400	600	250	400	600
Thickness under load 2 kPa	t_{GTX}	[mm]	2.5	3.5	4,0	2.6	3.7	4.9
Apparent Opening Size	O_{90}	[mm]	0.11	0.81	0.89	0.11	0.10	0.81
Hydraulic								
Velocity flow index (normal to the plane geotextiles)	v	[m/s]	2.2×10^{-2}	1.8×10^{-2}	1.9×10^{-2}	2.3×10^{-2}	1.9×10^{-2}	1.1×10^{-2}
Transmissivity flow (gradient, i = 0.1 under load 2 kPa)								
– Machine direction (normal)	$\Theta_{md.}$	[m^2/s]	2.2×10^{-3}	3.3×10^{-6}	4.4×10^{-3}	8.2×10^{-3}	1.2×10^{-2}	8.4×10^{-3}
– Machine direction (cross)	Θ_{cmd}	[m^2/s]	1.2×10^{-3}	3.2×10^{-6}	9.1×10^{-3}	1.5×10^{-2}	1.8×10^{-2}	9.5×10^{-3}
Mechanical								
Tensile strength								
– Machine direction (cross)	T_{cmd}	[kN/m]	10	18	26	9	16	18
– Machine direction (normal)	T_{mc}	[kN/m]	15	28	42	13	22	13
Static puncture by means CBR method	F_p	[kN]	2	3.5	4.8	1.7	3.0	2.8
Dynamic puncture	F_d	[mm]	9	3	2.9	15	5	3

TABLE 2.The norms used to test geotextiles materials

Properties	Norms
Physical Mass per unit area Thickness under load 2 [kPa] Apparent Opening Size	 PN-EN ISO 9864 PN-EN ISO 9863 PN-EN ISO 12956
Hydraulic Velocity flow index (normal to the plane geotextiles) Transmissivity flow	 PN-EN ISO 11058 PN-EN ISO 12958
Mechanical Tensile strength Static puncture by means CBR method, Dynamic puncture	 PN-EN ISO 10319 PN-EN ISO 12236 PN-EN ISO 13433

RESULT AND DISCUSSION

The results of tested technical properties of geotextiles are divided into three parts:

Physical properties of geotextiles

The changes of bulk density, for tested geotextiles under loads: 2, 20 and 200 kPa are showed in Figure 1. The bulk densities (Fig. 1) for both tested materials depend on values of strength of load. Geotextiles made of polypropylene (PP) had lower values of bulk density then values of bulk density of polyester fabric (PES).

The bulk density in geotextiles may be calculated using (Krzywosz et al. 2001):

$$\rho_d = \frac{\mu_A}{t_{GTX}} \quad [\text{kg/m}^3] \qquad [1]$$

where:
μ_A – mass per unit area [g/m^2],
t_{GTX} – thickness for the applied load of geotextiles [mm].

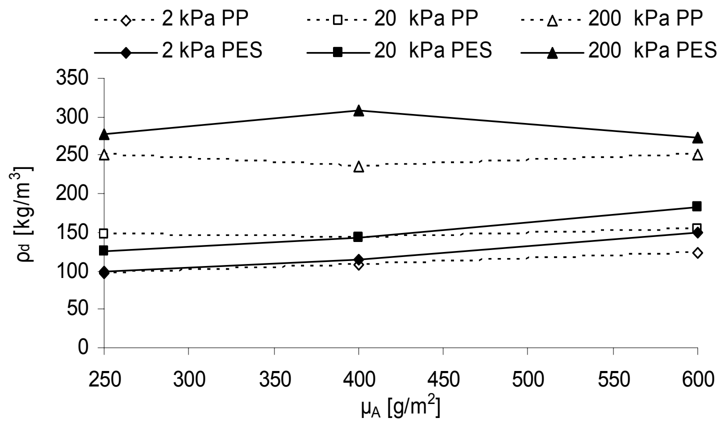

FIGURE 1. The change of bulk density (ρ_d) of geotextiles under load between mass per unit area (μ_A) of tested material

The changes of thickness of geotextiles under load between mass per unit area of geotextiles are presented in Figure 2. The values of thickness of tested geotextiles were highest for polypropylene material (PP) for each mass per unit area of fabric. The highest values of thickness were observed for geotextiles with about mass per unit area $\mu_A = 600$ g/m^2.

Results of tested porosity in geotextiles under load showed in Figure 3. The values of porosity for both materials decrease when mass per unit of these materials increase. Polypropylene geotextiles showed more values of porosity compared to porosity values of polyester geotextiles.

The variation of apparent opening size in geotextiles tests is presented in Figure 4. Results of O_{90} depended on geotextile porosity. There can be observed similar trends of result of tested different geotextile products. The values of apparent opening size in tested

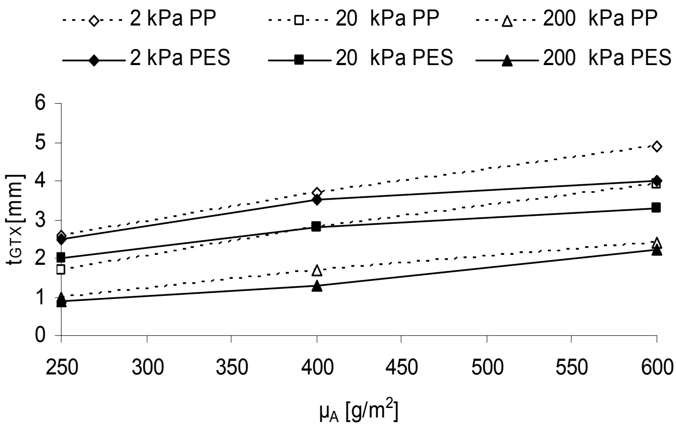

FIGURE 2. The change of thickness of geotextiles (t_{GTX}) under load between mass per unit area (μ_A) of tested material

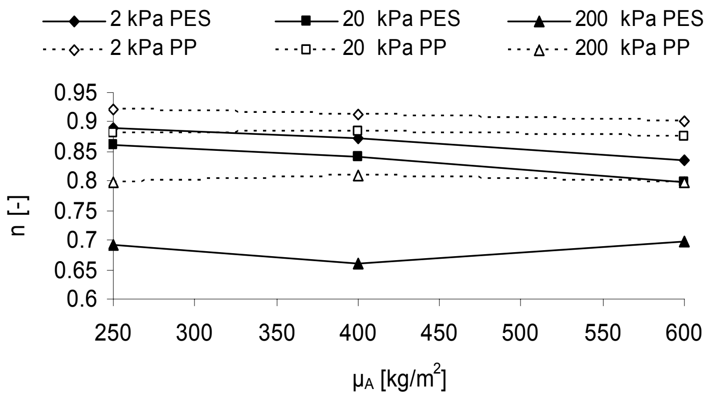

FIGURE 3. The change of porosity under load of geotextiles (n) between mass per unit area (μ_A) of tested material

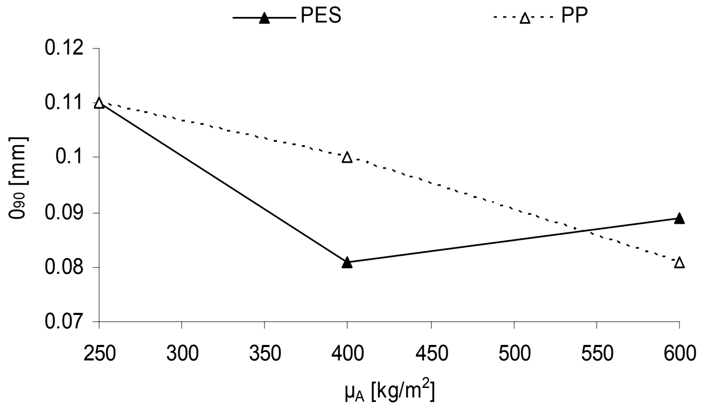

FIGURE 4. The change of apparent opening size (090) between mass per unit area (μ_A) of tested material

geotextiles decrease for materials which mass per unit area is higher.

Hydraulic properties of geotextiles

An analysis of the hydraulic characteristic of geotextiles depended on the direction of water flow through the tested sample. There are two directions of flows: normal to the plane flow (perpendicular to the sample) and cross plane flow.

Water flow velocity index (v-normal to the plane) variations versus the mass per unit area of materials showed in Figure 5. The results of tested velocity index in Figure 5 show that mass per unit area can significantly affect hydraulic properties of the geotextiles.

Cross plane flow (transmissivity) can be estimated in two cases: normal and cross to the sample (Fig. 6). First of them is flow water in accordance with the machine direction (θ_{md}) of fibers

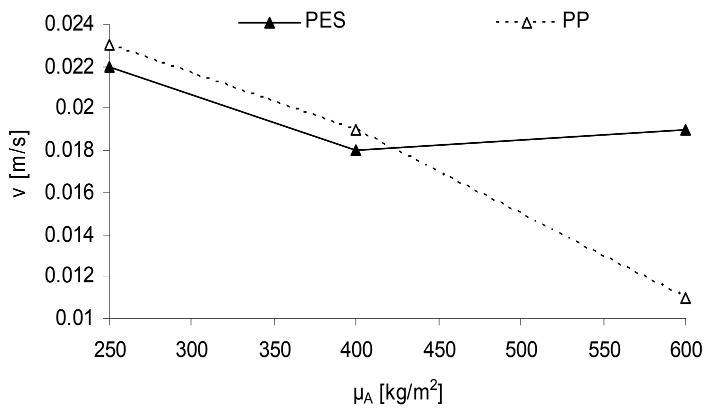

FIGURE 5. The change of velocity index flow (v – normal to the plane flow) of geotextiles between mass per unit area (μ_A) of tested material

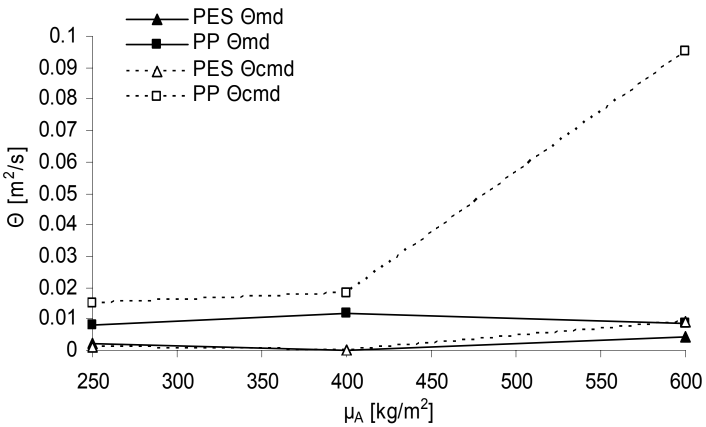

FIGURE 6. The change of transmissivity flow water of geotextiles (θ_{md} – machine direction and θ_{cmd} – cross machine direction) between mass per unit area (μ_A) of tested material

in geotextile material and the second is flow suitable the cross machine direction (θ_{cmd}) of filaments in geotextiles.

Result of tested (Fig. 6) characteristic of flow water through the geotextiles samples indicate that values of transmissivity flow depend on technology of materials production. Flow water in cross machine direction in polypropylene geotextiles had higher values than in polyester geotextiles.

Mechanical properties of geotextiles

Figure 7 shows the comparison between results obtained from analyses tensile strength (T_{md} – machine direction and T_{cmd} – cross machine direction).

The values of tensile strength of tested geotextiles increased in materials with higher values of mass per unit area. The analysis of tested geotextiles (Fig. 7) showed that tensile powers were totally different for each tested material.

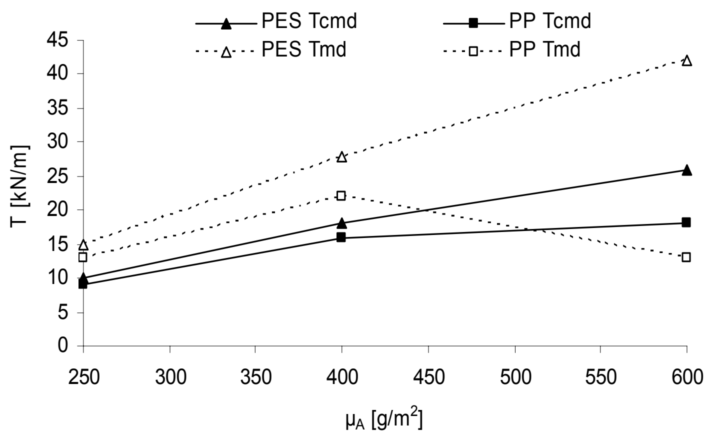

FIGURE 7. The change of tensile strength (T) of geotextiles (T_{md} – machine direction and T_{cmd} – cross machine direction) between mass per unit area (μ_A) of tested material

Another mechanical parameter of tested geotextiles is static puncture (Fig. 8). Results of tested static puncture showed that lower resistant of puncture was observed in polypropylene geotextiles. The results of tested fabric indicate that static puncture increased when mass per unit area of tested geotextiles was highest.

The dynamic punctures of tested geotextiles are presented in Figure 9. The values of it are totally different from values of static puncture test. The higher values are observed in tested geotextiles for fabric with lower mass per unit area. The values of dynamic punctures were decreasing when mass per unit area of tested product increased.

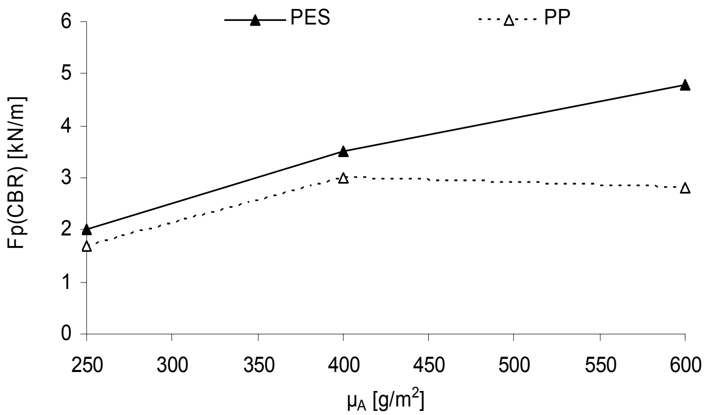

FIGURE 8. The change of static puncture (F_p – CBR method) of geotextiles between mass per unit area (μ_A) of tested material

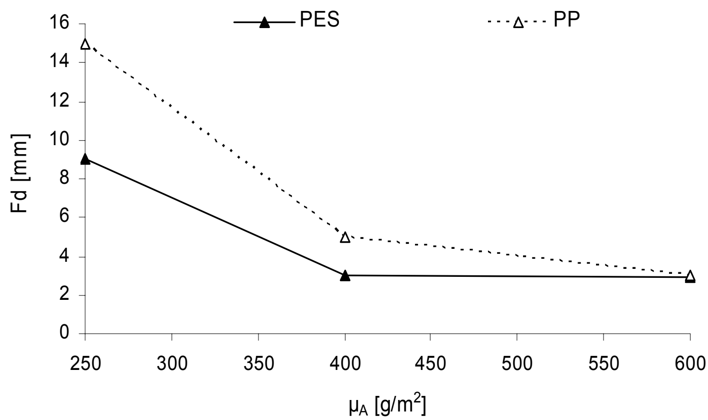

FIGURE 9. The change of dynamic puncture (F_d) of geotextiles between mass per unit area (μ_A) of tested material

CONCLUSIONS

1. The technical parameters of tested geotextiles were depended on component materials and their production structure.
2. The values of transmissivity flow and tensile strength of tested geotextiles were depended on the direction of situated samples during tested.
3. The bulk densities, the thickness and the static punctures values of tested fabrics increased in tested material together with the increase of values of mass per unit area of investigated product.
4. The parameters of tested geotextiles as: the porosity, the apparent opening size, the velocity index flow and dynamic puncture in fabrics decreased when mass per unit area of tested products was increased.

REFERENCES

KRZYWOSZ Z., WOJTASIK D. 2001: Methodology of testing the permeability normal to the plane of nonwoven geotextiles. Ann.Warsaw Univ. of Life Sci. – SGGW, Land Reclam. No 31, 57–64.

ROLLIN A.L. 1986: Filtration opening size of Geotextiles. ASTM Standardization News, 50–52.

Yeo K.C. 2008: Properties of geotextiles. Castco Testing Centre Limited, Hong Kong (www.hkpc.org/hkiemat/mastec03_notes/27.pdf)

PN-EN ISO 9864: 2007 Geosyntetyki. Metoda badań do wyznaczania masy powierzchniowej geotekstyliów i wyrobów pokrewnych. (Geosynthetics. Test method for the determination of mass per unit area of geotextiles and geotextile – related products).

PN-EN ISO 9863-1: 2007 Geosyntetyki. Wyznaczanie grubości przy określonych naciskach – Część 1: Warstwy pojedyncze. (Geosynthetics. Determination of thickness at specified pressures – Part 1: Single layers).

PN-EN ISO 12956: 2002 Geotekstylia i wyroby pokrewne. Wyznaczanie charakterystycznej wielkości porów. Geotextiles and geotextile-related products. Determination of the characteristic opening size).

PN-EN ISP 11058: 2002 Geotekstylia i wyroby pokrewne. Wyznaczanie wodoprzepuszczalności w kierunku prostopadłym do powierzchni wyrobu, bez obciążenia. (Geotextiles and geotextile related products. Determination of water permeability characteristics normal to the plane, without load).

PN-EN ISO 12958: 2002 Geotekstylia i wyroby pokrewne. Wyznaczanie zdolności przepływu wody w płaszczyźnie wyboru. (Geotextiles and geotextiles and geotextile-related products. Determination of water flow capacity in their plane).

PN-EN ISO 10319: 2008 Geosyntetyki. Badanie wytrzymałości na rozciąganie metodą szerokich próbek. (Geotextiles – Wide width tensile test).

PN-EN ISO 12236: 2007 Geosyntetyki. Badanie statycznego przebicia – metoda CBR. (Geotextiles and geotextile related products. Static puncture test – CBR test).

PN-EN ISO 13433: 2007 Geosyntetyki. Badanie dynamicznego przebicia – metoda spadającego stożka. (Geosynthetics. Dynamic perforation test – cone drop test).

Streszczenie: *Analiza fizycznych, hydraulicznych i mechanicznych właściwości igłowano-przeszywanych geowłóknin.* W artykule przedstawiono analizę parametrów technicznych geowłóknin igłowano-przeszywanych, wykorzystywanych w konstrukcjach inżynierskich. Testy przeprowadzono dla sześciu materiałów należących do dwóch grup produktów. Pierwsza grupa to geowłókniny powstałe na bazie polipropylenu, druga grupa to materiały syntetyczne z poliestru. Badane materiały posiadały masę powierzchniową 250, 400 i 600 g/m^2. Przeprowadzona analiza badań geowłóknin igłowano-przeszywanych wskazuje, iż skład surowcowy oraz kierunek produkcji włókien wpływa na parametry techniczne materiałów syntetycznych.

MS. received November 2008

Author's address:
Dariusz Wojtasik
Katedra Geoinżynierii – SGGW
02-776 Warszawa, ul. Nowoursynowska 159
Poland
e-mail: dariusz_ wojtasik@sggw.pl