Laboratory tests of artificial clogging of nonwoven geotextiles

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ABSTRACT: The paper presents the test results of the hydraulic characteristics of artificially clogged three types of nonwoven geotextiles. The specimens were artificially clogged in the laboratory according to the procedure created by authors by using a device used for determination of water permeability characteristics normal to the plane under load. In the central part of this device there was a soil layer (siSa) and beneath a nonwoven geotextile layer to allow the water vertical flow through the composite. Because of the water was flowing at constant time and certain water head, the specimen could be clogged. The artificial clogging procedure was created to reproduce natural in situ conditions. To observe mechanism of the artificial clogging 3D tomography was also used. The obtained results showed that the artificial clogging has an influence on the hydraulic characteristics of geotextiles. A significant reduction of the nonwoven geotextiles permeability due to physical artificial clogging was observed. The flow velocity and the velocity index for a head loss of 50 mm was constant after three hours of artificial clogging and around three times lower than at the beginning. It means that the specimen was clogged after three hours according to the procedure. It strongly depends on physical parameters of the geotextile, especially on characteristic opening sizes. If characteristic opening size was higher, the decrease of permeability was lower.

Keywords: nonwoven geotextile, artificial clogging, soil, permeability, flow velocity

1 INTRODUCTION

Nonwoven geotextiles have been used for filtration and drainage construction purposes in geoenvironmental and geotechnical engineering structures for four decades (Iryo and Rowe 2003, Liu and Chu 2006). Geosynthetic materials replace the natural materials, such as gravel and sand, with many advantages. They are easy to transport and install. Another factor for the use of nonwoven geotextiles is the cost and thickness reduction of filter layer (Bergado et. al. 2001, Palmeira et. al. 2008, Bhandari and Han 2010, Vieira et. al. 2010, Hong and Wu 2011).

However, in filtration applications the nonwoven geotextiles have direct contact with fine soil particles. The consequence of the fine particles accumulation in the geotextile is a negative process of physical clogging (Faure et. al. 2006, Wu et. al. 2006). Despite of many studies examining the behaviour of soil-geotextiles (Fannin et. al. 1994, Palmeira et. al. 1996, Wu et. al. 2006), mechanism of physical clogging is still not fully understood and not defined completely (McIsaac and Rowe 2007). Apart from the physical clogging in the drainage systems usually occurs biological and chemical clogging (Fleming and Rowe 2004, Koerner and Koerner 2015).

The nonwoven geotextiles used in drainage and filtration applications should meet the requirements: retention, permeability and anti-clogging capabilities. Filter design methods to ensure retention capability are based on relationship between the soil grain size and a characteristic pore size. Generally geotextile pores should be small to retain a significant amount of soil particles, whereas the permeability criterion requires larger pore sizes to ensure sufficient water discharge. The permeability criteria are ensured by examining the relative permeability of the soil and the geosynthetic.

Nonwoven geotextile selections based on these two criteria have not proven completely acceptable because clogging may occur despite satisfactory design criteria so the knowledge about this phenomenon is necessary to ensure durability of drainage systems (Wu et. al. 2008).

The objective of this paper is to study the influence of artificial physical clogging on the filtration characteristics of geotextiles. Due to that reason, the main experimental work was to determination of the water permeability in normal direction to the plane of clogged nonwoven geotextile samples. Examining water permeability helps to confirm that clogging has an effect on the hydraulic properties of geotextile used in drainage applications, because water permeability is a parameter that determines the application usability of this material in drainage and filter systems.

2 TEST PROGRAM

2.1 *Equipment and methodology used in the test*

Nonwoven geotextiles specimens were artificially clogged according to the procedure created by authors. Figure 1 presents the laboratory equipment, located in the Geotechnical Laboratory at Slovenian National Building and Civil Engineering Institute.

In the central part of this device, used generally to determination of water permeability normal to the plane under load, the specimen was placed on the silty sand (15 mm thickness) layer. Afterward the water was flowing through this composite in constant time and water head (at first through the soil and then through the nonwoven geotextile) to allow to clogged specimen. Very important was focus on avoiding empty space where the composite is in contact with the cylinder because water has to flow through the entire surface of the soil and nonwoven geotextile. Load of 10 kPa was enough to protect the composite before lifting up.

Depending on physical parameters of three tested nonwoven geotextiles different water head was used during artificial clogging process because water flow should be steady. For that reason, during this process necessary was to increase value of head loss, for samples I – from 15,5 to 41 mm, samples II – from 32,5 to 60 mm and for samples III – from 110 to 300 mm.

To check and observe the artificial clogging process after 10, 30, 50, 60, 70, 80, 100, 120, 150, 180 minutes the flow velocity and the velocity index for a head loss of 50 mm of geotextiles was determined according to ISO 11058:2011.

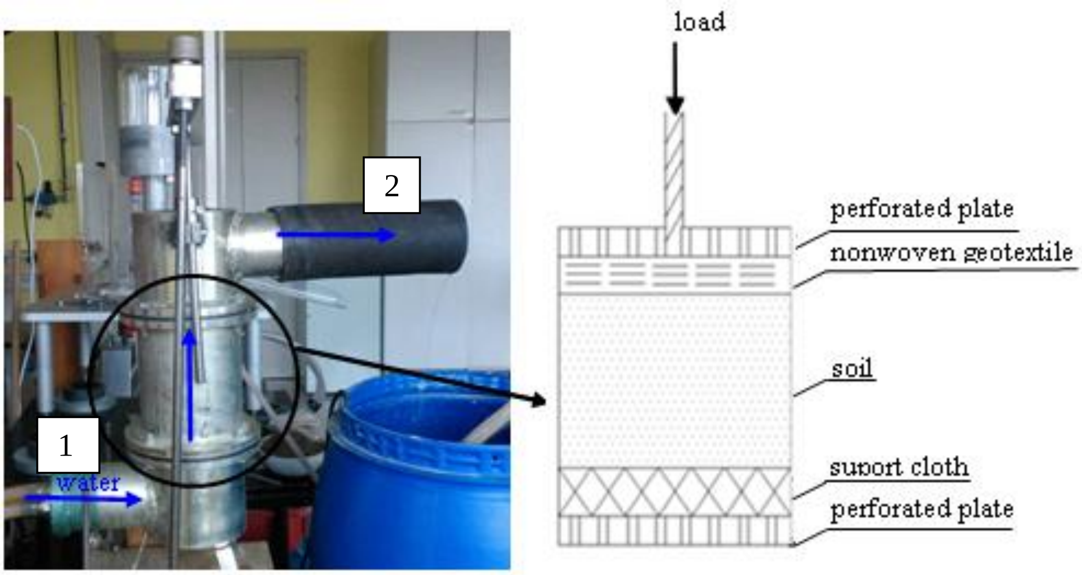

Figure 1: The test stand (1- inflow, 2- outflow)

2.2 *Materials*

Three nonwoven geotextiles (I, II and III) have been used in tests, for which characteristics are presented in Table 1.

Table 1. Characteristics of the nonwoven geotextiles tested

Geotextile Type	Thickness (mm)	Mass per Unit Area (g/m^2)	Opening Size (μm)	Tensile Strength CMD$^{(*)}$ (kN/m)	Tensile Strength MD$^{(**)}$ (kN/m)
I	2,0	200	100	14,5	16,0
II	2,6	280	80	24,0	20,3
III	4,5	450	83	27,1	26,7

Notes: $^{(*)}$CMD = cross machine direction, $^{(**)}$MD = machine direction

Artificial clogging of the geotextile specimens with soil particles was made under laboratory with the use of silty sand. Silty sand is a soil mixture with coarse and fine grains.

The used soil had a density of ρ = 1,78 Mg/m^3, d_{50} = 0,17 mm, d_{85} = 0,65 mm with the particle size distribution curves shown in Figure 2. Soil had 31% of total weights passing through 0,063 mm sieve (#230 according to US Standard Mesh).

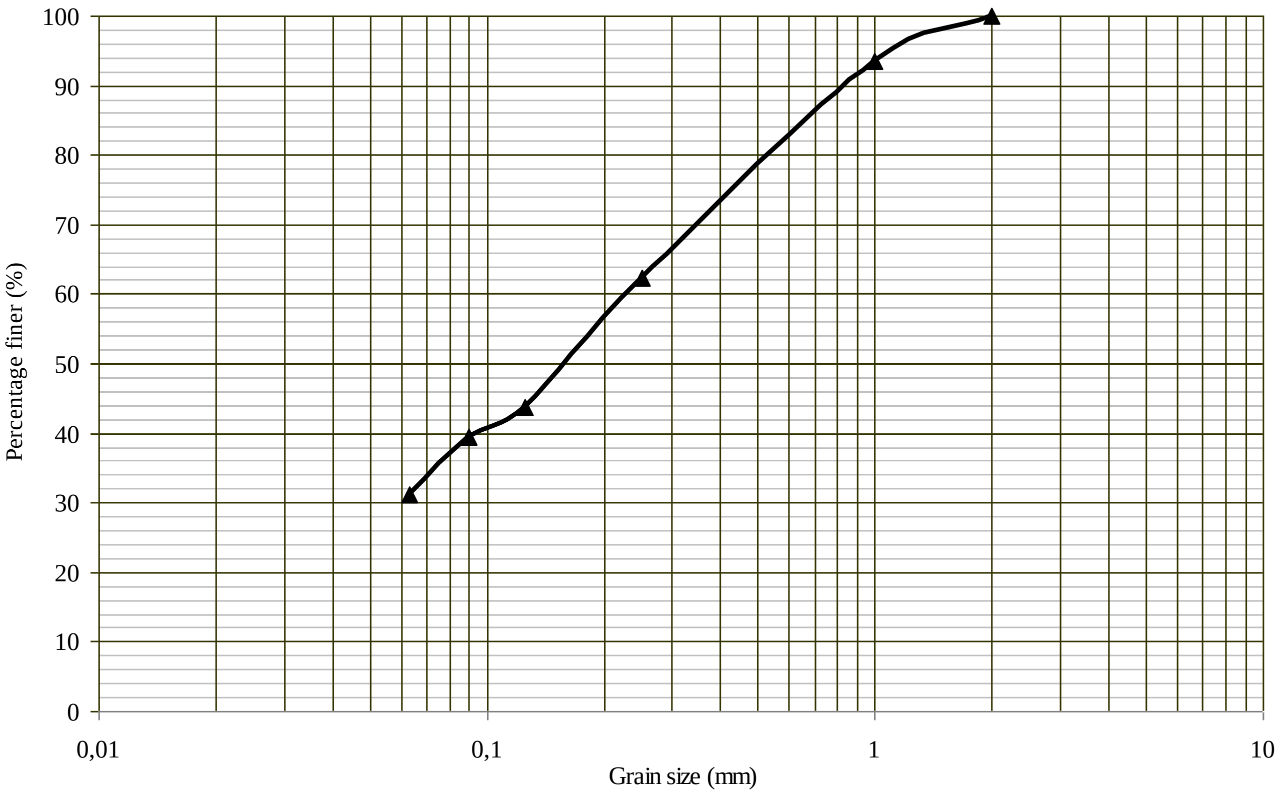

Figure 2: Particle size distribution curve of the silty sand (siSa)

Artificial clogging in laboratory mainly depends on characteristics opening size and thickness of tested nonwoven geotextiles and fine grains of used soils so properly selection of these materials is really important to perform this test.

3 RESULTS AND DISCUSSION

Geotextile samples before and after tests are showed in Figure 3.

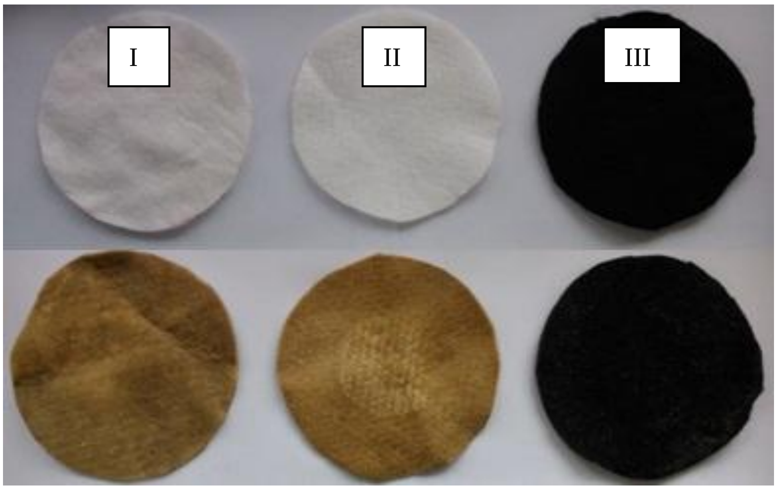

Figure 3: Geotextile samples before (at the top) and after tests (on the bottom)

It is obvious that after tests the specimen were clogged. Due to it the color of geotextile samples was darker. After the flow tests, carried out for each sample, with a determined head loss, the flow velocity (v_{20}) was calculated using the following empirical formulae (PN-EN ISO 11058:2010) to state without a doubt the changes of water permeability.

$$v_{20} = \frac{V \cdot R_t}{A \cdot t} \text{ (m/s)} \qquad (1)$$

where V = water volume measured (m^3), R_t = correction coefficient for water of temperature of 20ºC (2), A = exposed specimen area (m^2), t = time measured to achieve the volume V (s).

$$R_t = \frac{1{,}762}{1 + 0{,}0337 \cdot T + 0{,}00022 \cdot T^2} \text{ (-)} \qquad (2)$$

where T = water temperature during the tests (ºC).

Having compiled test results, the flow velocity indicator (V_{H50}) was calculated for water head equals to 50 mm, based on the obtained curve equation. Water permeability coefficient (k_n) was calculated for the same value of hydraulic thrust (3).

$$k_n = \frac{V \cdot g}{A \cdot t \cdot \Delta h} \text{ (m/s)} \qquad (3)$$

where g = thickness of tested material under given load (m), Δh = pressure differential under and over the specimen, expressed as the height of water column (m).

Figure 4 shows the relationship between the velocity of water flow and water head for the tested geotextile samples before (clean samples) and after artificial clogging.

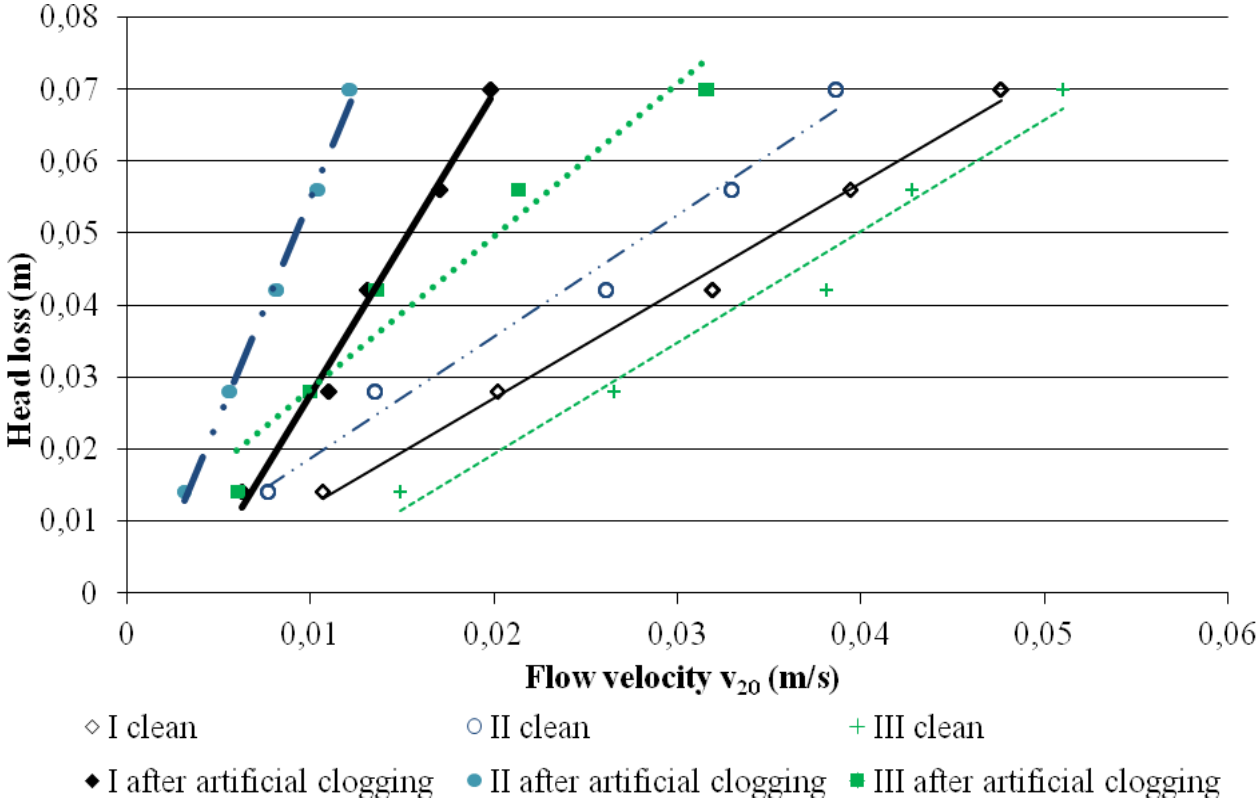

Figure 4: Flow velocity characteristics for tested nonwoven geotextile samples

Based on the obtained results, it was concluded that the flow velocity for the samples after artificial clogging is approximately 3 – 4 times lower than the flow velocity for the unworn one. Table 2 compares the calculated flow velocity index of the nonvoven geotextiles.

Table 2. The values of flow velocity index V_{H50} for tested nonwoven geotextile samples

Type of geotextile	V_{H50} for unworn nonwoven geotextile (m/s)	V_{H50} for nonwoven geotextile after artificial clogging (m/s)	Decrease of V_{H50} (%)
I	0,033	0,014	58
II	0,026	0,008	70
III	0,035	0,018	48

After 180 minutes of artificial clogging, water flow velocity index at the water head of 50 mm decreased even by 70% in case of sample II. This indicates that mechanical clogging has big influence on hydraulic properties of nonwoven geotextiles.

Changes of water permeability coefficient (k_n) in time are showed in Figure 5. For tested nonwoven geotextiles the change of k_n is almost constant after 120 minutes of artificial clogging. In that reason the tests were terminated at 180 minutes of elapsed time as the water permeability coefficient and flow velocity index reached relatively stable values for all tests.

Work presented by Giroud (1982) suggests that the permeability of the geotextile installed in a soil has to be only 10 times greater than the soil permeability at all times. The permeability coefficient of the silty sand is about $k_{soil}=10^{-6}–10^{-5} m·s^{-1}$ (Terzaghi et. al. 1996), hence the condition is met even after 180 minutes of mechanical clogging.

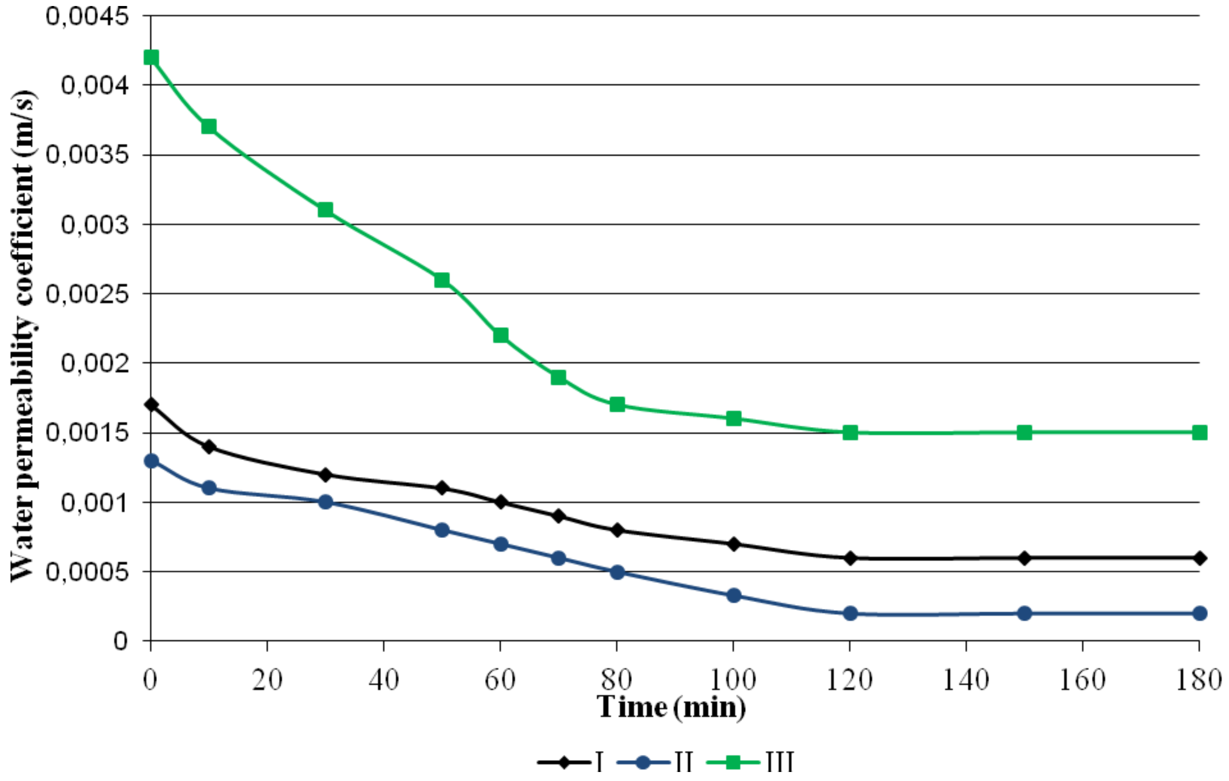

Figure 5: Changes of water permeability coefficient in time

Changes of hydraulic properties of nonwoven geotextiles during artificial clogging process mainly depend on physical properties: opening size, thickness or mass. According to Table 2 and Figure 5, the biggest decrease of hydraulic properties was observed in case of sample II. This nonwoven geotextile had the smallest characteristic opening size. In turn, sample III had the biggest thickness and mass so decrease of hydraulic properties was the smallest. Figure 6 shows decrease of water permeability coefficient of nonwoven geotextiles after clogging.

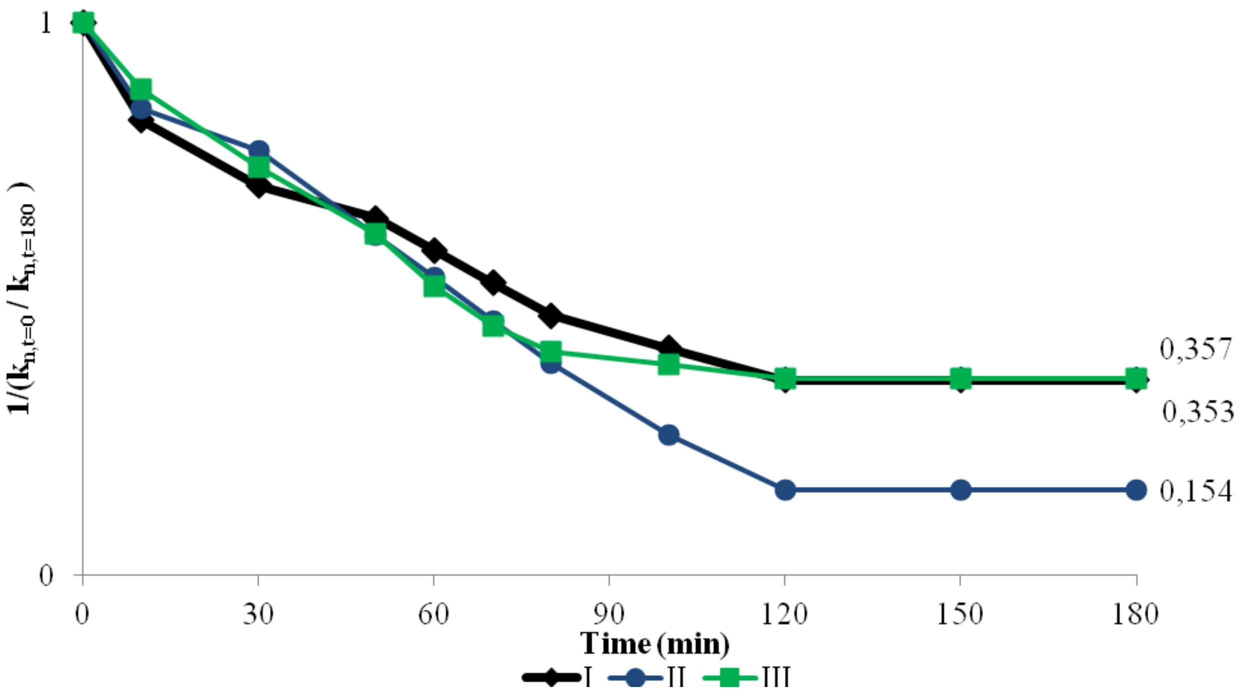

Figure 6: Decrease of water permeability coefficient after artificial clogging

4 CONCLUSIONS

The results obtained allowed to confirm influence of artificial clogging on hydraulic properties of tested nonwoven geotextiles.

Changing of water permeability coefficient in time depends on physical parameters of nonwoven geoetxtile, especially on thickness, mass and characteristic opening size. The biggest decrease of hydraulic properties was observed in case of sample II.

Based on tests which are showed in paper, artificial clogging in laboratory may last 120 minutes. Despite of this, unequivocal presentation of the relationship between mechanical clogging and decrease of hydraulic parameters of geotextiles requires further research taking into account production technologies, different mechanical and physical properties.

Biological and chemical clogging requires additional research. Both the biological, chemical and mechanical clogging should be included in the criteria of selection of geotextiles filter layers.

5 ACKNOWLEDGMENTS

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