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Influence Of Geotextile Filters On The Discharge Capacity Of Geocomposite Drainage Materials.

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ABSTRACT: Different geotextile filters are used in combination with drainage cores to form geosynthetic composite materials for drainage applications. These filters vary in manufacturing process and properties and are mostly characterized based on their results in mechanical and hydraulic index testing. Seven nonwoven filters and their effect on the discharge capacity of geocomposite drain material have been analysed. The discharge has been analysed under different loads and in contact with soil. The stress-strain behaviour of the filter has shown a significant influence on the total discharge capacity. Higher energy absorption at 10% stress results in higher retained discharge capacity under load while maximum stress shows no or little influence on the result. The study showed significant differences in stress-strain and energy absorption characteristics for the different geotextile filters.

1. INTRODUCTION

Geosynthetic drainage composites are products used to drain surface water, ground water or gas from civil engineering and building works. Common applications include drainage of landfills, bridge abutments, basements, tunnels, and roads. They are usually supplied in sheet or roll form and consist of two components:

- A drainage core (geospacer) that transmits the fluid in the plane of the product to a collector or similar outlet. It needs to combine high in-plane flow capability with structural stiffness so that it does not collapse under load. Usually these spacers are made of random wire, cuspated films or geonets.
- A filter fabric that may be attached to one or both sides of the core, depending on core type and application. Their function is to filter the incoming fluid so that solid particles may not get into the core and cause clogging of the drainage layer. Due to their filtration properties (high permeability and high amount of different opening sizes), usually nonwoven geotextile filters are used.

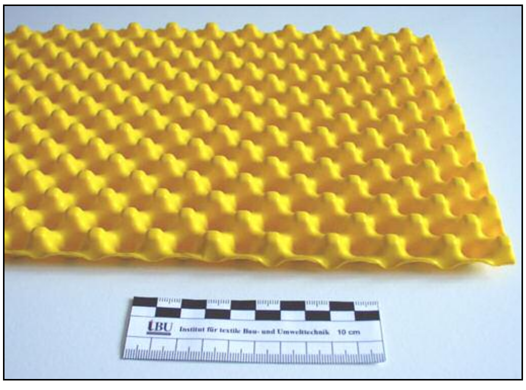
Many manufacturers offer different fixed filter products for the same drainage core depending on specifications and installation conditions. On some sites the core and the filter materials are delivered by different suppliers and assembled or installed separately by the contractor. Under these conditions it is however essential to know the discharge capacity associated with each different combination.

2. PRODUCTS

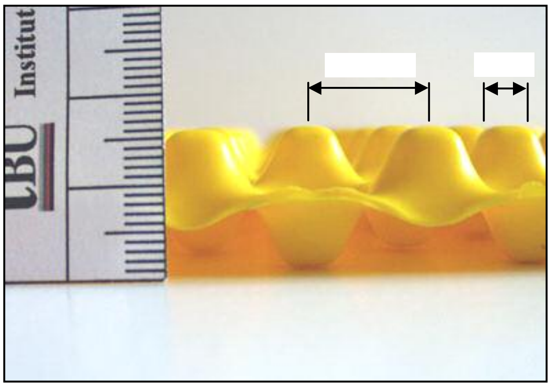
The products used in this investigation are:

Drainage Geospacer

The draining core consisted of a symmetrical thermoformed sheet of PEHD. The cuspated studs are formed on both sides of the product (see picture 1 and 2)



Picture 1: Geospacer



Picture 2: Geospacer detail

Geotextile filters

A range of commonly used nonwoven polypropylene geotextiles manufactured by different process technologies and of differing weights and mechanical properties was selected. The selected products were as follows

- TH-B100: thermally bonded, continuous fibres, 100 g/m²
- NP-CF105: needle-punched, continuous fibres, 105 g/m²
- NP-SF120: needle-punched, short fibres, 120 g/m²
- TH-B136: thermally bonded, continuous fibres, 136 g/m²
- TH-B190: thermally bonded, continuous fibres, 190 g/m²
- NP-CF200: needle-punched, continuous fibres, 200 g/m²
- NP-SF200: needle-punched, short fibres, 200 g/m²

2.1 Product properties

Product properties of the used materials are given in table 1 and 2.

Table 1: Geospacer Index Properties

Property	Standard	Unit	
Mass per unit area	EN 965	g/m²	2330
Thickness at 2 kPa	EN 964 P1	mm	16.30
Thickness at 20 kPa	EN 964 P1	mm	16.15
Thickness at 100 kPa	EN 964 P1	mm	15.98
Thickness at 200 kPa	EN 964 P1	mm	15.75
Dimples	---	Dimples/m²	1600

Table 2: Filter Index Properties

Property	Standard	Unit	Th-B 100	NP-CF 105	NP-SF 120	Th-B 136	Th-B 190	NP-CF 200	NP-SF 200
Area Weight	EN 965	g/m²	102	103	126	141	187	204	209
Thickness at 2 kPa	EN 964-1	mm	0.42	1.12	0.82	0.50	0.68	1.73	2.66
at 20 kPa	EN 964-1	mm	0.34	0.78	0.68	0.43	0.60	1.32	1.79
at 100 kPa	EN 964-1	mm	0.30	0.59	0.57	0.39	0.55	1.06	1.19
at 200 kPa	EN 964-1	mm	0.29	0.52	0.52	0.38	0.54	0.90	0.98
MD Tens. Str.	EN 10319	kN/m	6.5	8.4	5.9	8.6	12.4	16.3	8.4
CMD Tens. Str.	EN 10319	kN/m	6.5	8.2	10.5	8.7	11.7	17.2	12.5
MD Elong.	EN 10319	%	53.1	101.1	79.5	46.5	62.7	80	67.5
CMD Elong.	EN 10319	%	56.1	39	61.9	53.1	62.0	75	51.2
Opening Size	EN 12956	mm	0.160	0.120	0.070	0.110	0.100	0.080	0.090
Velocity Index	EN 11058	mm/s	82	120	81	59	49	87	93

2.2 *Stress-Strain Properties of Geotextile Filters*

In addition to standard tensile strength and elongation at maximum load according to EN ISO 10319, the following additional properties have been determined.

- Energy absorption W:

  The work done to elongate a specimen to a given tensile stress or strain in a tensile test. It is defined by the integral of (the area under) the stress/strain curve to a chosen point, and expressed in kJ/m². Alternatively in some specifications it is also expressed in kN/m.

  Example: Energy Absorption W at maximum load (Wmax)

  Energy Absorption (Wmax) is the work expressed in kilojoules per square meter and calculated directly from the data obtained from the tensile testing machine.

- Energy absorption index , W-index

  An approximate calculation of energy absorption at maximum load:

  W-index = 0.5 • T_{max} • ε

  T_{max} - tensile strength,

  ε - elongation at maximum load

- Energy absorption and tensile strength at a given % of strain

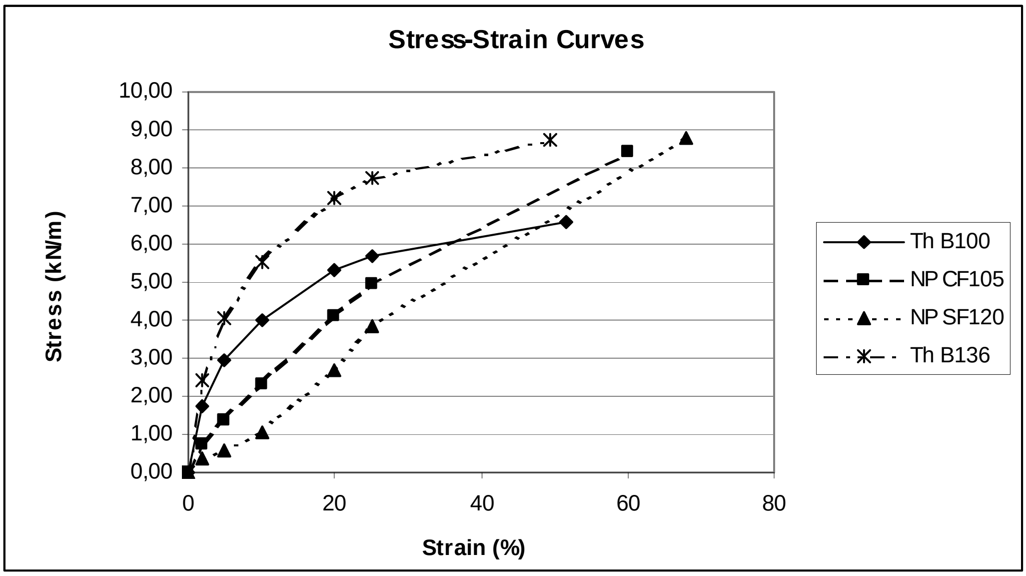


Figure 1: Stress-Strain curves of low weight filter products (100 g/m²-136 g/m²)

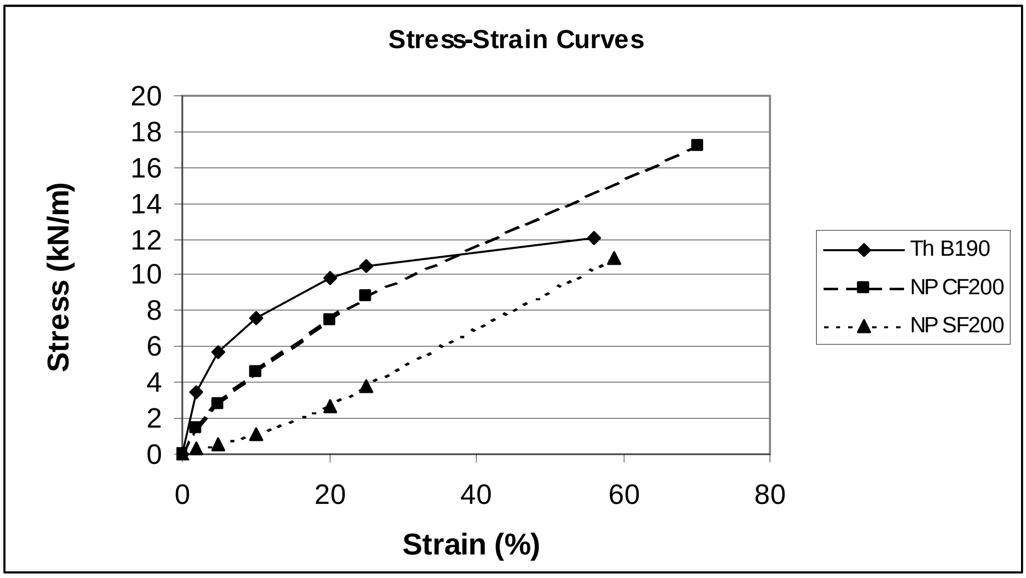


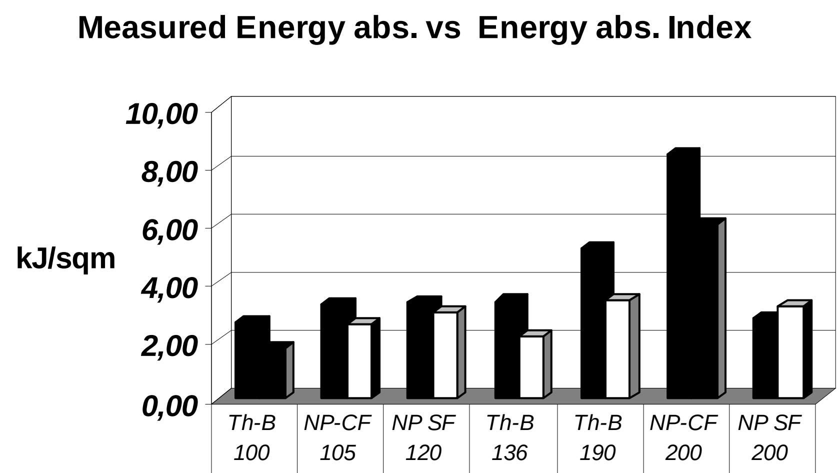
Figure 2: Stress-Strain curves of heavier weight filter products (190 g/m²-200 g/m²)

Table 3: Properties taken from test results according EN ISO 10319

Property	Unit	Th-B 100	NP-CF 105	NP-SF 120	Th-B 136	Th-B 190	NP-CF 200	NP-SF 200
MD Tensile Strength	kN/m	6.5	8.4	5.9	8.6	12.4	16.3	8.4
CMD Tensile Strength	kN/m	6.5	8.2	10.5	8.7	11.7	17.2	12.5
Avg. Tensile Strength MD/CMD	kN/m	6.5	8.3	8.2	8.7	12.1	16.8	10.5
MD Elongation	%	53.1	101.1	79.5	46.5	62.7	80.0	67.5
CMD Elongation	%	56.1	39.0	61.9	53.1	62.0	75.0	51.2
Avg. Elongation MD/CMD	%	54.6	70.1	70.7	49.8	62.4	77.5	59.3
Avg. Energy Absorpt. MD/CMD	kJ/m²	2,62	3,26	3,32	3,33	5,20	8,40	2,77
Avg. Energy Abs. Index MD/CMD	kJ/m²	1,71	2,53	2,96	2,16	3,39	6,01	3,18
Avg. Energy at 10% Strain MD/CMD	kJ/m²	0,75	0,47	0,35	1,02	1,42	0,89	0,25

2.3 Energy absorption measurements

Several specification systems and test studies claim that the damage resistance of geotextiles is directly related to their energy absorption. While some studies show a good correlation with measured energy absorption at maximum strength, some studies and specification systems prefer the simplified approach of energy absorption index. If these principles can also be used for filters in geocomposite drainage materials was not analyzed in this study. It has to be noticed however that there is a significant difference between “real” energy absorption and energy absorption index. For most products the simplified calculation of energy absorption index is significantly lower than the measured energy absorption varying (up to 35% for the thermally bonded products). For other products like the tested short fiber needle-punched product, the index value may be higher than the measured one (see figure 3).



	Th-B 100	NP-CF 105	NP SF 120	Th-B 136	Th-B 190	NP-CF 200	NP SF 200
■ Energy abs.	2,62	3,26	3,32	3,34	5,20	8,40	2,77
□ Energy abs. index	1,71	2,53	2,96	2,16	3,39	6,01	3,18

Figure 3: Energy absorption at maximum load versus energy absorption index

3. DISCHARGE CAPACITY MEASUREMENTS

The discharge capacity measurements were carried out according EN ISO 12958 “Determination of water flow capacity in their plane”. The test principle is that the flow of water within the plane of a geosynthetic is measured under varying normal compressive stresses, typical hydraulic gradients and defined contact surfaces. The standard surfaces contacting the specimen should be two layers of foam rubbers. When the product to be tested has been designed to perform its hydraulic functions against rigid boundaries, the foam rubber membranes should not be used.

To carry out the tests, specimen (200 mm x 300 mm) of the drainage core were cut. Each specimen had the same number of dimples and the nonwoven layers were fixed on both sides of core with hot melting glue on the surface of each dimple.

3.1 Index test EN ISO 12958 versus real conditions.

The discharge capacity highly depends on the material that is in direct contact with the filter when the load is applied. The rigid plates do not allow any deformation of the filter product and so these results cannot be used when the drainage composite is in contact with soft materials like soil or flexible membranes. To assume reliable results, EN ISO 12958 uses flexible and soft foam plates that should ensure a similar behaviour like surrounding soil under in situ conditions. Additional to the tests according the standard tests with soil on both sides were carried out. The soil characteristics were:

- Loess soil
- d_{10} = 0,003 mm, d_{20} = 0,012 mm, d_{80} = 0,05 mm, d_{90} = 0,1 mm
- Dencity after compaction (dry) 1,64 g/cm³ (95% Proctor)
- Water content 19,9 %

Figure 4 shows the discharge capacity with Th-B 136 and NP-CF 200 using standard soft foam plates compared to soil.

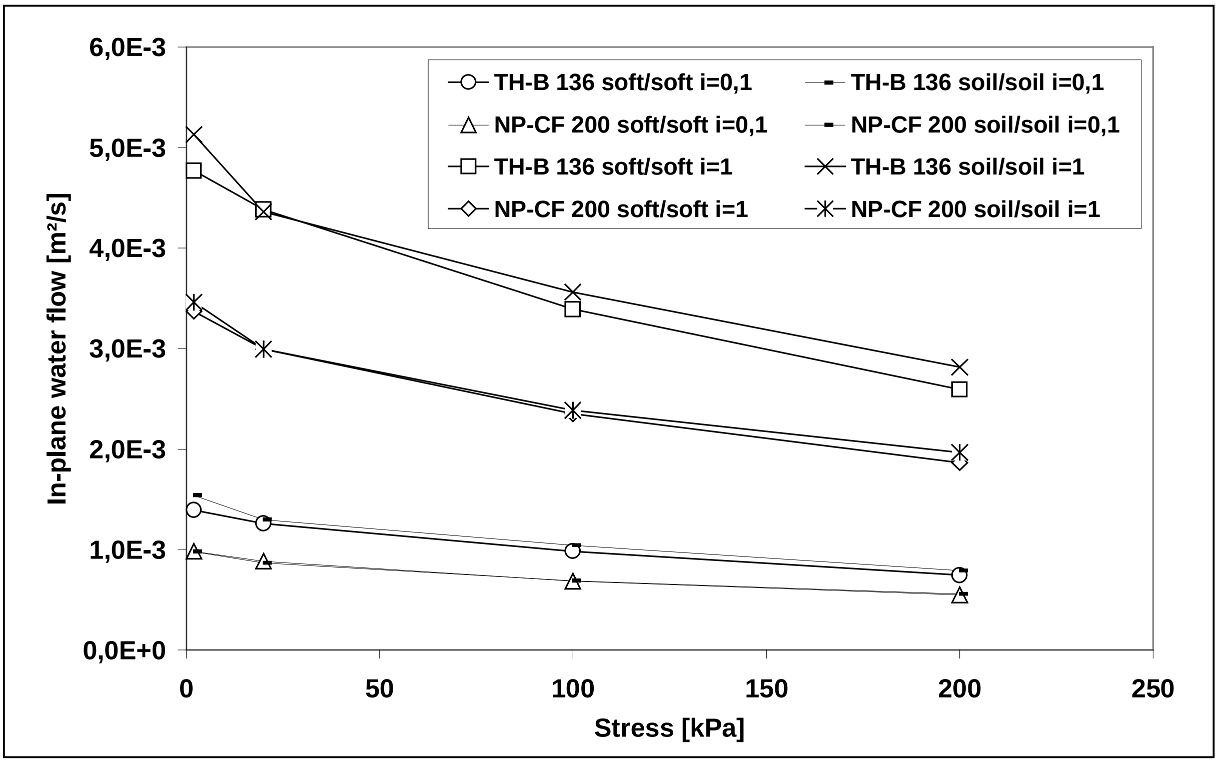


Figure 4: Comparison of test results with foam plates (soft/soft) and soil on both sides.

A good similarity of short time behaviour was obtained between the soil and the foam plates so that the discharge capacity on the different composite materials could be tested using the standard foam plates (see also picture 3 and 4).

Picture 3: TH-B 136 soil/soil (after compaction to 95% Proctor)

Picture 4: NP-CF 200 soil/soil (after compaction to 95% Proctor)

3.2 Discharge capacity depending on used filter product

Table 4.1 and 4.2 show the discharge capacity for each type of geotextile filter. The retained discharge capacity has been calculated compared to the maximum possible discharge capacity of the draining core obtained by using rigid plates without filter on both sides of the draining core (see table 4).

Table 4: Discharge capacity (m²/s), drain core only

Product	Discharge i = 0.1	Discharge i = 1	Retained (%) i =0.1	Retained (%) i = 1
Drain Core (Rigid / Rigid)				
2 kPA	1,59E-03	5,55E-03	100	100
20 kPA	1,43E-03	5,14E-03	100	100
100 kPa	1,36E-03	4,81E-03	100	100
200 kPA	1,28E-03	4,57E-03	100	100

Table 4.1: Discharge capacity (m²/s), low weight filter products

Product	Discharge i = 0.1	Discharge i = 1	Retained (%) i =0.1	Retained (%) i = 1
Th-B 100				
2 kPa	1,29E-03	4,40E-03	81	79
20 kPa	1,16E-03	3,95E-03	81	77
100 kPa	8,95E-04	3,03E-03	66	63
200 kPa	6,83E-04	2,28E-03	53	50
NP-CF 105				
2 kPa	1,15E-03	3,98E-03	72	72
20 kPa	9,77E-04	3,32E-03	68	65
100 kPa	6,45E-04	2,44E-03	47	51
200 kPa	4,53E-04	1,76E-03	35	39
NP-SF 120				
2 kPa	1,34E-03	4,47E-03	84	81
20 kPa	1,09E-03	3,69E-03	76	72
100 kPa	6,83E-04	2,31E-03	50	48
200 kPa	4,69E-04	1,57E-03	37	34

Product	Discharge i = 0.1	Discharge i = 1	Retained (%) i =0.1	Retained (%) i = 1
Th-B 136				
2 kPa	1,39E-03	4,77E-03	88	86
20 kPa	1,26E-03	4,38E-03	88	85
100 kPa	9,85E-04	3,39E-03	72	71
200 kPa	7,44E-04	2,59E-03	58	57

Table 4.2: Discharge capacity (m²/s), heavier weight filter products

Product	Discharge i = 0.1	Discharge i = 1	Retained (%) i =0.1	Retained (%) i = 1
Th-B 190				
2 kPa	1,37E-03	4,67E-03	87	84
20 kPa	1,27E-03	4,27E-03	89	83
100 kPa	9,96E-04	3,45E-03	73	72
200 kPa	8,16E-04	2,74E-3	64	60
NP-CF 200				
2 kPa	9,84E-04	3,37E-03	62	61
20 kPa	8,82E-04	2,99E-03	62	58
100 kPa	6,87E-04	2,35E-03	50	49
200 kPa	5,49E-04	1,87E-03	43	41
NP-SF 200				
2 kPa	9,35E-04	3,32E-03	59	60
20 kPa	6,72E-04	2,34E-03	47	46
100 kPa	3,87E-04	1,40E-03	28	29
200 kPa	2,79E-04	1,01E-03	22	22

The discharge capacity for each composite changes with the hydraulic gradient (for i = 0.1 or 1). The hydraulic gradient has however no influence on the % retained discharge capacity for each different composite and so the following figures and correlations are all given at a hydraulic gradient of 0.1 (see figure 5).

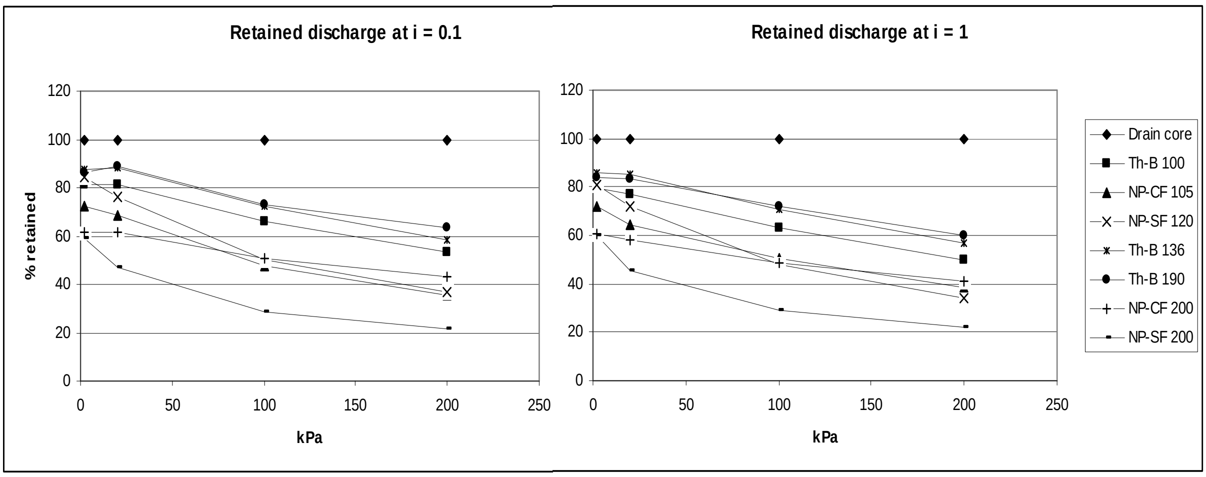


Figure 5: Retained discharge capacity versus applied pressure at i = 0.1 and 1.0

The discharge capacity varies with the used filter product and applied load.

Even at a minimum load of 2 kPa the discharge is immediately reduced. The retained discharge for the thermally bonded products is between 81 and 88% and for needle punched products between 59% and 84%. At 2 kPa the loss of discharge also seems to be related to the thickness of the product. The thinner and lighter weight needle-punched products have 72% and 84% retained discharge while the heavier weight needle-punched products have about 60% retained discharge. At higher loads (20 and 100 kPa) the discharge however is reduced to the same level all the for needle-punched products. No correlation was found between maximum tensile strength and discharge capacity (figure 6).

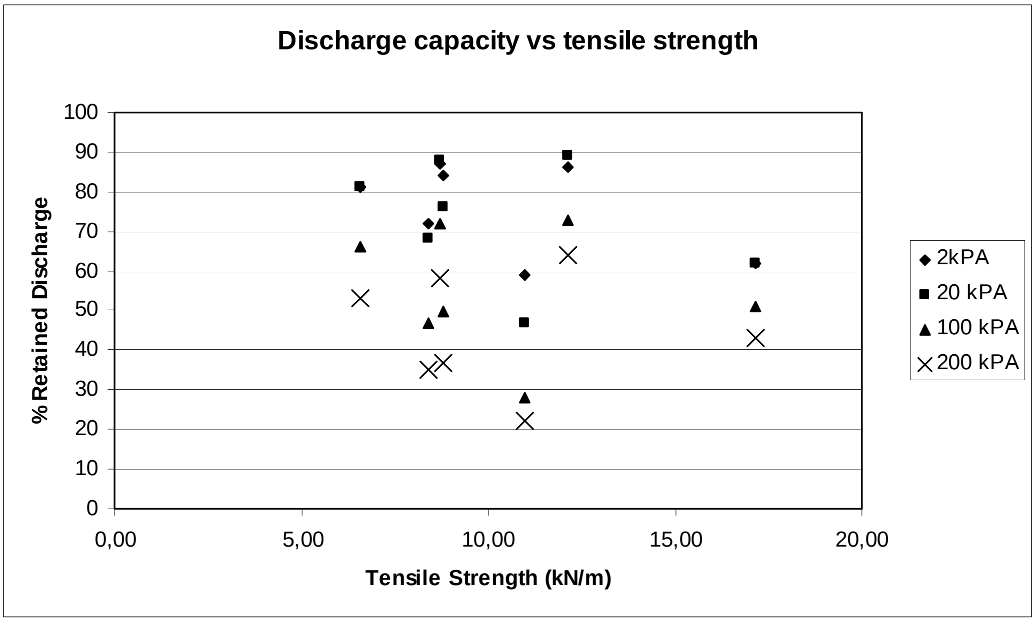


Figure 6: Discharge capacity vs tensile strength

A good correlation is obtained however with the absorbed energy at 10% of strain. The higher the energy absorption potential at 10% of strain, the higher the retained discharge capacity. This correlation is validated for all applied loads (2 to 200 kPa) on the drainage composite (figure 7).

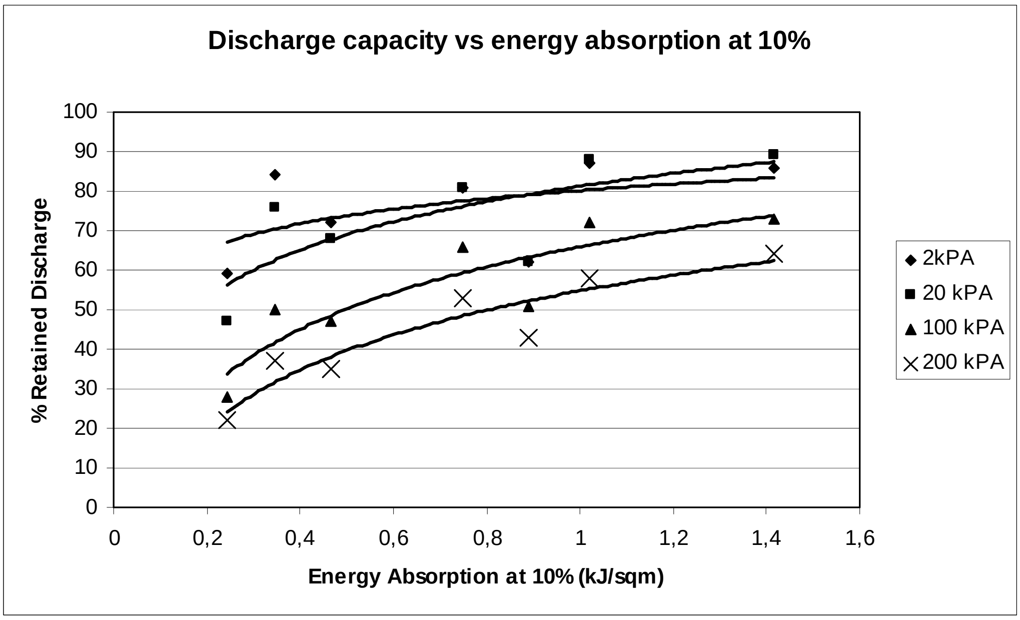


Figure 7: Retained discharge capacity versus energy absorption at 10% of strain

Quite a significant loss of discharge capacity is obtained at applied loads of 100 or 200 kPa for some of the products. All the tested needle-punched products have about 50 % or higher loss at a load of 100 kPa. The highest and fastest loss in discharge capacity is however obtained with product NP-SF200. At low load (2 kPa) already 40% of maximum possible discharge capacity is lost. A loss of 53% is obtained at 20 kPa which further drops to 78% at 200 kPa. The relatively low energy absorption potential of this product at lower strains (figure 2) results in higher deformations. This consequently reduce the discharge capacity which is given by the free area of the tested drainage core.

4. CONCLUSIONS

The discharge capacity tests with standard foam plates and soil demonstrate in the short time test (according EN ISO 12958) a similar behaviour. This proves that the standard index test is good to show the deformation effect under in situ conditions.

The index tests on the filters show that due to different stress-strain behaviour a simplified calculation of energy absorption index is not appropriate to show the real energy absorption potential of a geotextile.

The results show that the discharge capacity of geosynthetic composite drainage materials with low flexible core is directly affected by the applied load and by the geotextile filter used. All tested variations show a reduction in theoretical discharge capacity due to deformation of the filter under the effect of load. This deformation however varies significantly with the stress-strain behaviour of the geotextile filter. Already at applied loads of 2 kPa some geocomposites with a thicker flexible needle-punched filter result in high loss of discharge capacity. At higher loads, a clear correlation is obtained between retained discharge capacity and the energy absorption potential of the filters at 10% stress. Higher energy absorption at a given % strain results in lower deformation and thus reduces the loss of discharge capacity under load.

The study demonstrates that an exchange of geotextile filters with a same drainage core cannot be done without determining the discharge capacity on the total composite under the given conditions.

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