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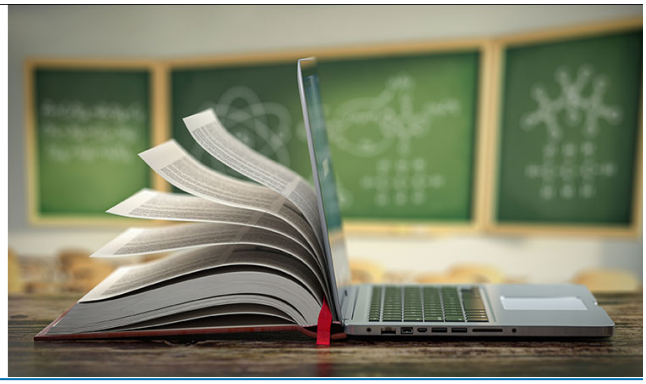

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Random sampling of geosynthetics in Finland

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Abstract. NorGeoSpec is a Nordic system for certification and specification of geosynthetics and geosynthetic related products. Traffic authorities of the member states have composed the guidelines and agreed on a 5-class specification system for geotextiles used for filtration and separation. Recently the quality certification system has been extended to include the reinforcement function, too. The classification system has made the specification of geotextiles easy for the designer, thus increasing the use.
The NorGeoSpec process includes a third-party quality control and audits, i.e. an inspection of the production process and testing of the products in an independent testing laboratory, in addition to the producers' continuous quality testing. Also, continuous surveillance including unannounced random product sampling and control checks is possible.
With the support of NorGeoSpec, Finnish Transport Infrastructure Agency has carried out a random products sampling on geotextiles and reinforcing geosynthetics in 2015-2018. In addition, random sampling was made on roadside groundwater protection projects using geosynthetic clay liners and geomembranes.
The random sampling project has increased the knowledge of geosynthetics. The results of random sampling have shown some deviations from requirements and the variation between laboratories. Based on the results, the requirements on sampling and testing prior the use at the project site to prove the compliance has been added to Finnish general quality requirements (InfraRYL).

1. Introduction

Geosynthetics have been widely used in various applications to improve the soil behaviour, especially to increase the structural tensile strength and deformation properties. The most commonly used products are filter geotextiles, which can be used in waterways, road and railway construction as well as in house construction. On the 20th century, the product selection has increased, the quality and the knowledge the risen based on research and development work and the use of geosynthetic products has increased and applications expanded worldwide. However, there is still lack of knowledge and even prejudices limiting the use of geosynthetics.

In the Nordic system for certification and quality control of geosynthetics and geosynthetic-related products, i.e. NorGeoSpec system, traffic authorities of the member states Finland, Sweden, Norway and Estonia, certain independent test laboratories and SINTEF Certification as the NorGeoSpec certification body work together in a process for certification and specification of geosynthetics and geosynthetic related products. [1,2]

NorGeoSpec started as a Nordic scheme for certification, specification and inspection of geotextiles used for separation and filtration in roads, based on application standard EN 13249 [1]. The classification system of geotextiles used in trafficked areas has simplified the specification of a geotextile and opened the market for nonwoven filter geotextiles. The NorGeoSpec classification is based on formed VTTGeo system developed in Finland [1]. The NorGeoSpec system has been applied in Finland since 2003, and it has been implemented into national guidelines presented in InfraRYL.

In the NorGeoSpec, the Quality Product Certification (QPC) and Quality Product Specification (QPS), are given to a manufacturer who applies for it, on condition that the product concerned satisfies the rules currently published in the NorGeoSpec 2012 Guideline. The certification and specification of geotextiles is based on a set of characteristic properties determined by standard test methods defined by CEN and ISO. The NorGeoSpec quality control process includes a third-party quality control and audits, i.e. inspection of the production process and testing of the products in an independent NorGeoSpec testing laboratory. The NorGeoSpec system provides also guidelines for selecting relevant specification profile based on site-specific subsoil conditions, the granule size of the filling material and a combination of road-building conditions, as well as the road's quality requirements. [2]

On the initiative and with financial support of the traffic authorities in Finland, Sweden, Norway and Estonia the NorGeoSpec2002 guideline dealing with the separation and filtration functions have been extended to include the reinforcement function. The NorGeoSpec 2012, a Nordic system for certification and specification of geotextiles and geotextile-related products includes function reinforcement besides the former combined functions filtrations and separation. Relevant application standards are EN 13250, EN 13251, EN13525, EN 13256, EN 13257, EN 13265 ja EN 15381. [2]

2. NorGeoSpec certification process

The base of the quality control is the producers' continuous quality testing according to their quality program. The factory production quality control is required for a CE marking, which is a requirement for products placed on the market in the European Union and in Norway, Iceland and Liechtenstein. According to the Construction product Regulation (CPR), the manufacturer must document by the CE-mark that he takes the conformity of the product with the declared performance. The CE marking is based on Declaration Performance (DoP), where the producer presents the values based on product testing and the defines the tolerances for a different test. The essential characteristics to be presented in the DoP is determined in the harmonized technical standards. [3]

However, the producer of the geosynthetic products is allowed to perform all necessary test in his own laboratory, since the geotextiles and other geosynthetics belong to the AVCP-class (Assessment and Verification of Constancy of Performance) 2+. In that class, the certification body only checks and certificates the conformity of the factory production control, and no external testing of the quality is required.[3]

The aim of NorGeoSpec is to support the choice of geosynthetics in specific situations. It is a voluntary system helping to reduce the cost of designing the simple structures and the project-specific quality control measures and simplify comparison of the products within strict competition rules. [2]

To evaluate whether geotextiles and geotextile related products comply with the requirements of NorGeoSpec and are suitable for Nordic soil conditions, a two-part product certification procedure is used. In part 1, the quality of the product is determined. In part 2, the suitability of the product for the specific use is assessed. The part 1, the Product Certification, must in all cases precede part 2, the Product Specification. At present, the specification is only available for geotextiles used for separation and filtration in roads, and Product Certification only for functions separation and filtration, and reinforcement. [2]

In NorGeoSpec, a minimum lifetime of 25 years is required for all functions. The products for which approval is requested must have a CE Mark in accordance with the relevant hen Application Standard(s). The manufacturer must have a documented system for the factory production control. Any changes in raw materials, in production methods or in the methods used to monitor production quality must be made known immediately, as well as a change in the DoP (Declaration of Performance). [2]

2.1. Product Certification

The aim of the Product Certification is to ensure that the quality of the products meet the requirements, and to guarantee that this quality is maintained for a product lifetime equal to or greater than 25 years.

The NorGeoSpec certification process includes a third-party quality control and audits. The process starts with a primary inspection of the production process and an initial testing of the products in an independent NorGeoSpec testing laboratory. The data of the producers' continuous quality testing is evaluated. These activities are complemented by repeating the production inspection, and by re-taking samples and carrying out material testing, at regular intervals. [2]

The scope of testing for Product Certificate is presented in Table 1. Test values and tolerance(s) for the following properties are included: Tensile strength and elongation (EN ISO 10319), energy index, static puncture test (EN ISO 12236), dynamic perforation test (EN ISO 13433), characteristic aperture size (EN ISO 12956) and permeability (EN ISO 11058). [2]

NorGeoSpec laboratories are mandated by the NorGeoSpec Certification Body, which is SINTEF. Within the NorGeoSpec system the laboratories perform tests on samples received from the inspection agent. The results of the tests are sent to the NorGeoSpec Certification Body. No direct contact is permitted between the testing laboratory and the producer in connection with an application for NorGeoSpec certification. In order to ensure that the NorGeoSpec laboratories operate at a comparable, high level of testing quality, they are required to participate in a programme of continuous improvement of testing quality organised by SINTEF. [2]

Table 1*:* Certified values with tolerance (in % of values) depending on the function fulfilled by the product (NorGeoSpec 2012 Guideline, Part 1, Annex C) [2].

Characteristic	**Standard**	**Unit**	**Function**		
Product identification			*Filtration*	*Separation*	*Reinforcement*
Mass per unit area [a]	EN ISO 9864	g/m^2	± 10 %	± 10 %	± 10 %
Tensile elements	Annex F		n.r.	n.r.	Manufacturer's data
Dimensions	Annex F [b]	mm	n.r.	n.r.	± 15 %
Mechanical tests					
Max tensile strength	EN ISO 10319 [c]	kN/m	-10 %	-10 %	n.r.
Tensile strain at max tensile load	EN ISO 10319	%	-20 %	-20 %	n.r.
Nominal tensile strength	EN ISO 10319	kN/m	n.r.	n.r.	-5 %
Tensile strain at nominal strength	EN ISO 10319 [c]	%	n.r.	n.r.	± 20 %
Tensile stiffness at 2, 5, 10% tensile strain	EN ISO 10319	kN/m	n.r.	n.r.	-20 %
Static puncture test	EN ISO 12236	kN	-10 %	-10 %	-10% [d]
Dynamic perforation resistance	EN ISO 13433	mm	+25 %	+25 %	+25% [d]
Hydraulic tests					
Permeability normal to the plane without load	EN ISO 11058	mm/s	-30 %	-30 %	-30 % [d]
Characteristic opening size	EN ISO 12956	µm	±30 %	±30 %	±30 % [d]

[a] The plus/minus NGS-tolerance on the mass per unit area is regarded as an indication of the process stability. Process stability means that the process delivers constant, predictable results.
[b] Applicable only for geogrids (definition acc. EN ISO 10318).
[c] MD and CMD direction. For uniaxial products, test only the direction of load uptake
[d] Voluntary
n.r. = not required

The compliance of the product with the NorGeoSpec requirements is declared by the NorGeoSpec certification body. The Technical Committee reviews the evaluation results and decides whether the compliance should be declared. The certification body issues the Certificate and publishes it on the website. The Certification is valid for 2 years. Production audits including sampling are carried our during this period and selected properties are measured to confirm that the quality is remaining at the required level. This continuous surveillance involves unannounced sampling at production sites, at the warehouse, and on construction site. [2]

At the time of certification, the producer (or other applicant for the certification, such as importer of distributor) should publish the same nominal value for each required characteristic for the NorGeoSpec as for the DoP. [2]

2.2. Product Specification

The aim of the product specification is to guide and simplify the use of geotextiles for separation and filtration.

The products are classified into five specification profiles based on seven characteristics measured with test methods defined by CEN and ISO. In addition, the system includes guidelines for the selection of the relevant specification profile, based on the subsoil conditions, the maximum grain size of the fill material and a combination of construction conditions and quality requirements for the road. The required values for five profiles are presented in Table 2. [2]

The subsoil is divided into two groups, Soft and Firm. The construction conditions are also divided into two groups, normal and favourable based in amount of heavy construction traffic, sharpness of the fill material, need for compaction and vibrating equipment and thickness of the fill layer. In addition, the traffic load is divided into two classes: high (more than 500 vehicles per day) and low (less than 500 vehicles per day). Based on these input parameters, the selection of the suitable specification profile can be made according to Table 3.[2]

Table 2*:* Required values for product Specification profiles. Function: separation and filtration (NorGeoSpec 2012 Guideline, part 2, Annex A) [2]

Characteristic	**Testing standard**	**Unit**	**Maximum tolerance[a]**	**Required [b] values corresponding to 95% confidence limit**				
				Product specification profiles				
				1	2	3	4	5
Minimum tensile strength	EN ISO 10319	kN/m	-10%	6	10	15	20	26
Elongation at maximum load	EN ISO 10319	%	-20%	15	20	25	30	35
Maximum cone drop diameter	EN ISO 13433	mm	+25%	44	38	28	22	13
Minimum energy index		kN/m		1.2	2.1	3.2	4.5	6.5
Minimum velocity index	EN ISO 11058	10^{-3} m/s	-30%	3	3	3	3	3
Maximum characteristic opening size, O_{90}	EN ISO 12956	mm	±30%	0.2	0.2	0.2	0.15	0.15
Maximum tolerance for mass per unit area	EN ISO 9864	g/m^2	±10%	-	-	-	-	-
Maximum tolerance for static puncture strength	EN ISO 12236	kN	-10%	-	-	-	-	-

[a] The tolerance shall be stated by the manufacturer; this table gives the maximum allowable tolerance.
[b] The tolerances are not to be added to the required values. The nominal values ± the tolerance shall fulfil the requirement.

Table 3*:* Selection of relevant Specification profiles for function separation and filtration (NorGeoSpec 2012 Guideline, part 2, Annex B) [2].

Subsoil	**Construction conditions**	**Traffic**	**Maximum grain size (d_{max}) in fill material**			
			d_{max} < 63 mm	63 mm < d_{max} < 200 mm	200 mm < d_{max} < 500 mm	d_{max} > 500 mm
Soft	Normal	High	3	4	5	5
		Normal	3	4	4	5
	Favourable	High	3	3	--	--
		Normal	2	3	--	--
Firm	Normal	High	2	3	3	4
		Normal	2	2	3	3
	Favourable	High	2	2	--	--
		Normal	2 [a]	2	--	--

[a] Specification profile 1 may be used for roads with temporary traffic, access roads or similar.

3. Random sampling

In NorGeoSpec system, also unannounced random product sampling and control checks are possible [2]. However, the products are typically transported directly to the project site and there are seldom products in the storage of the producer or distributer available for random sampling. In Norway, the Norwegian Public Roads Administration has been performing sampling and testing of geotextiles used in road projects in their own laboratory since 2007 [4]. They have detected several quality deviations. For example, in 2017 they tested 91 nonwoven geosynthetics, and 6 of them were below requirement. Four of failing products belong to class 4, and two to class 3 [5]. On the other hand, while the number of yearly tested samples has increased, the portion of failing has decreased, probably due to the increased focus on quality.

Therefore, a random sampling on site was organized in Finland in co-operation with The Finnish Transport Infrastructure Agency to gain experience on sampling geosynthetics on site.

The sampling was a part of larger random sampling project of the Finnish Transport Infrastructure Agency, which started in 2014. The aim of this random sampling project was to study the properties of materials used in construction and maintenance of road and railway structures. One of the main objectives was to compare the actual quality of materials and existing operational quality standards. In 2014 and 2015 the sampling was concentrating on aggregates used in road and railway structures. In 2016, geosynthetics used in road construction projects, and geosynthetic clay liners and geomembranes used in roadside groundwater protection projects were included. [6]

The first random sampling of geotextiles took place in 2015 as part of the random checks carried out by NorGeoSpec. The random sampling on NorGeoSpec certified geotextiles and reinforcing geosynthetics was organized with the support of NorGeoSpec. The sampling shall meet the requirements of EN ISO 9862. To ensure the quality of sampling, the persons taking samples were trained by SINTEF, which is acting as the NorGeoSpec certification body. The guidelines for sampling are presented in Annex D of NorGeoSpec 2012 Guideline, Part 1 [2].

The main principle in sampling on rolls is to take two samples, A and B sample, from two different rolls. The rolls for sampling should be chosen based on roll numbers, as far from each other as possible. The width of the sample equals to the roll width and the length depends on the test program, based on standard EN ISO 9862. The beginning of the roll, two full circles, is always removed before sampling. [2]

The samplers must take particular care to ensure that the product is marked in accordance with EN ISO 10320. The roll information such as machine direction, roll number and sampling date is documented both to the roll and a sampling record together with the sampler's signature (figure 1). The samples are packed with care and protected from UV.

Figure 1. Sampling and marking of a geotextile on construction site

The A sample is tested first. If the result is outside the tolerances times 1 -1.5, the B sample is tested. If the deviation is larger, the product is failing.

3.1. Sampling and testing of NorGeoSpec certified geotextiles

The planning of the random sampling started with the survey on on-going or future construction projects were geosynthetics are used to identify the possible sampling site. The samples were mainly taken from road projects. To cover as wide product range as possible, three samples were taken from a landfill construction site. [6]

In 2015 and 2016 a total of 20 samples were taken, of which 18 samples were geotextiles and two reinforcing geosynthetics. To validate the effect of the laboratory and to evaluate the laboratory performance, parallel samples of four geotextiles were sent to two different laboratories. The other laboratory was part of the NorGeoSpec system. In total, four laboratories were used in testing and three of them were NorGeoSpec laboratories. [6]

The testing program was varying, depending on the purpose of the sampling. Part of the samples were taken for NorGeoSpec and part only for the Finnish Transport Infrastructure Agency. The mass per unit area (EN ISO 9864) reflecting the homogeneity of the production and the tensile strength and elongation (EN ISO 10319) were tested from all samples. The testing program is presented in table 4.

The sampling is covering 13 geotextile products, from which 11 samples were representing NorGeoSpec Class 3, three samples Class 4 and four samples Class 5. [6]

Table 4*:* Amount of geotextile samples and the testing program in random sampling 2015-2016 [6].

Characteristic	**Standard**	**Number of samples**	
		2015	**2016**
Mass per unit area	EN ISO 9864	11 (+ 2 parallel)	5
Tensile strength and elongation	EN ISO 10319	11 (+ 2 parallel)	5
Thickness	EN ISO 9863-1	4	
Dynamic perforation test (cone drop)	EN ISO 13433	4	1
Characteristic aperture size	EN ISO 12956	9	2
Static puncture test	EN ISO 12236		1
Permeability	EN ISO 11058		1

3.2. Sampling of reinforcing geosynthetics

Since the use of reinforcement is still a quite new solution, it was difficult to find projects for sampling. In 2015 and 2016 one project was involved in sampling, both using the same product. From reinforcement, the tensile strength and grid apertures and dimensions were tested in two NorGeoSpec laboratories [6].

In 2017 the strength and strain characteristics of four reinforcements were tested. Unfortunately, the laboratory was not following the standard EN ISO 10319 in measuring the elongation. The testing laboratory was no part of NorGeoSpec system. [7]

3.3. Sampling of geosynthetic clay liners and geomembranes

In 2016 geosynthetic clay liners were sampled from one ground water protection construction site. The A and B samples were exceptionally taken from the same roll. [6]

In 2017, geosynthetic clay liners used for groundwater protection on two road projects were studied. In addition, a sample of thin geomembrane was taken at one site. [7]

In 2018 geomembrane coated geosynthetic clay liner used for groundwater protection was sampled from two road projects. A thin HDPE-liner was clued to the GCL. The tests were performed in two laboratories to evaluate the testing protocols. [8]

The testing of geosynthetic clay liners consists of measuring the mass per unit area of clay geosynthetic barriers (EN 14196) and swelling index of bentonite (ASTM D 5890). The test samples were cut according to standard EN 14196. The theoretical amount of bentonite was calculated from results based on the water content of the bentonite and the nominal mass per unit area values given by the producer for the geotextiles. For the thin geomembrane, the mass per unit area was determined according to the standard EN ISO 9864, and the theoretical thickness was calculated. [6,7,8]

4. Results

The results of performed tests were compared with the DoPs, data sheets and NorGeoSpec certificates referring to the tested products. The results from geosynthetic clay liners and geomembranes were also compared to the general quality requirements set in InfraRYL (General Quality Specification for Infrastructure) valid at the time of the construction contract and referred in the project specifications [9].

In figure 2, the results of the mass per unit area of geotextile samples taken 2015-2016 are presented to illustrate the range of variations.

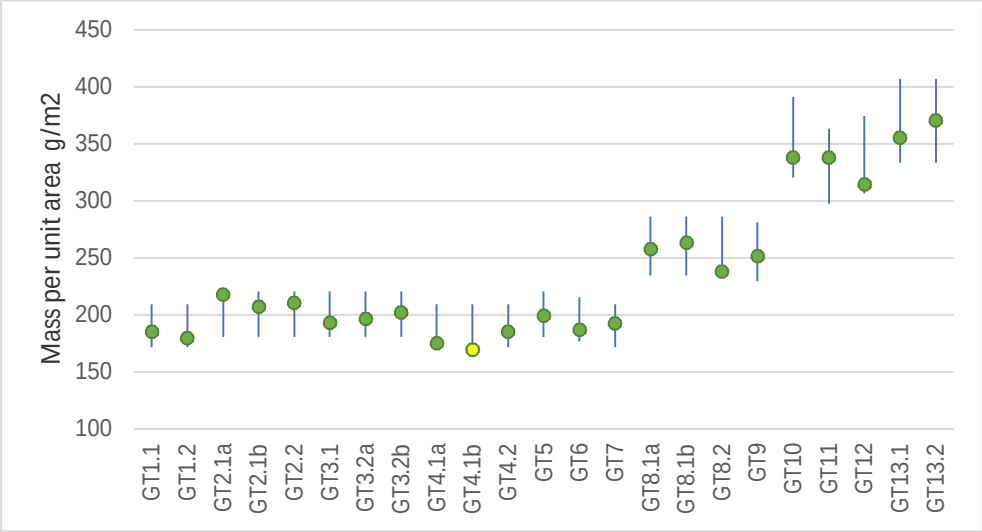

Figure 2. The results of mass per unit area and the range of variation declared for NorGeoSpec. First number is the product symbol, second number the mark for parallel or corresponding samples tested in another laboratory and the letter is referring to A and B samples. [6].

Only one mass per unit area result (GT4.1b) was outside the range of variation declared for NorGeoSpec by the producer. Four geotextile products tested in 2015-2016 failed and three was approved after testing a B sample, all based on the tensile strength and elongation results. In other words, the B tests confirmed that they actually met the requirements. In failed products the deviations were so major that the products represent a lower profile class. [6]

The parallel samples of two products which were tested in two laboratories both fulfilled the requirements. No clear tendency was detected, when the parallel results of laboratories were studied. [6]

Both reinforcement products tested in 2015 and 2016 fulfilled the requirements [6]. Based on the results of four reinforcement tested in 2017 in a non-NorGeoSpec laboratory, all four products failed either based on the elongation, tensile strength of both. However, since the laboratory hadn't followed the testing standard and didn't have much previous experience on testing reinforcement products, these results were rejected, and no actions were taken. [7]

The required bentonite amount in the geosynthetic clay liner used for the roadside protection was at least 3 800 g/m^2 and the swelling index should be at least 24 ml/2g [9]. Geosynthetic clay liners tested in 2016 products fulfilled the requirements, but the products sampled in 2017 and 2018 failed. In 2017, one had too low swelling index, and the other had too low bentonite weight per square metre. In B samples the swelling index was acceptable, but the bentonite amount was even lower than in corresponding A sample. Products sampled in 2018 had too low bentonite amount, but the swelling index was acceptable. [6,7,8]

The geomembrane sampled in 2017 gave a significantly lower mass per square metre than the nominal value given by the producer. The calculated thickness didn't fulfil the minimum requirement (0,5 mm). [7]

5. Conclusions

The random sampling of geotextiles and reinforcing geosynthetics was performed for a first time in summer 2015 as a part of NorGeoSpec a third-party quality control. Number of sampling and testing was quite limited, especially when reinforcing geosynthetics and liners are considered.

The results of random sampling have shown some deviations from requirements and the variation between laboratories, too. In general, a half of the test results of geotextiles is not meeting the requirements. Typically, the deviations are minor and testing of the B sample is providing acceptable results. However, one third of the products are failing to fulfil the requirement of at least one tested property. Based on the results, the random sampling is a necessary part of the third-party quality control.

The potential negative effect of transportation and handling on site on the quality was recognized. In addition, the site conditions such as weather and soil conditions are affecting on the quality of the samples. Therefore, the results of the random sampling are not affecting on the NorGeoSpec product certification. However, the results not fulfilling the requirements are reported both to the client and producer, and to the NorGeoSpec Inspector, too, and they might lead to the checking of producers quality control results and additional or more frequent sampling from the storage or factory [2].

The random sampling project has significantly increased the knowledge and understanding of geosynthetics, especially the persons involved. Based on the results, the requirements on sampling and testing prior the use at the project site to prove the compliance has been added into updated Finnish general quality requirements (InfraRYL).

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