Specification profile for geotextiles for separation and filtration in roads – Norwegian standard

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ABSTRACT: A new Norwegian standard for specification of geotextiles was introduced in august 1999. The new standard includes a specification profile system for requirements for geotextiles for separation and filtration in roads. The new specification profile system is based on the experiences from the old classification combined with a research project including laboratory tests, large scale model tests and full scale field tests. The new specification profile includes requirements on minimum tensile strength and minimum elongation at failure obtained by the wide with tensile test, maximum hole size from the cone drop test and a newly developed criteria on minimum strain energy based on the wide with tensile test. The strain energy criteria assumes that a certain amount of the strain energy is "absorbed" during the construction period and that a certain "reserve" of strength and strain should be available for the service lifetime. The specification profile input is subsoil conditions, maximum stone diameter of material adjacent to the geotextile and construction equipment and procedures.

1 INTRODUCTION

1.1 *The classification system used by the Norwegian Directorate of Roads*

The Norwegian Directorate of Roads has for more than 20 years been using a classification system for geotextiles for separation and filtration in roads. The classification requirements are mainly empirically based and to some extent adapted to specific Norwegian soil conditions and experience (Alfheim, Sørli 1978). The classification system was originally developed for internal use at the Norwegian Road Administration. The classification principles with some revisions were later adopted also in Sweden and Finland (Rathmayer 1994).

The existing classification system divides geotextiles for separation and filtration in roads into four classes dependent on the type of material (maximum grain size) to be used against the geotextile:

Class 1: Minimum criteria
Class 2: Sand and gravel with max. diameter 50 mm
Class 3: Crushed stone with max. diameter 100 mm
Class 4: Blasted rock with max. diameter 2/3 of the layer thickness

The classification is based on an evaluation of results from the static puncture tests (CBR-test) and the cone drop tests. The tested product will achieve points from the results in the tests referring to each criterion and the classification is then dependent on the total sum of points. For the static puncture test the measured force and deformation are used to calculate a corresponding tension (force/length) and strain (%). The classification is based on criteria for maximum tension, the elongation strain at failure and the tension increase from 20 % to 70% strain (or until strain at failure if less than 70%). For the cone drop test the average diameter of the hole made by the falling cone is used as evaluation criterion (Schalin 1995).

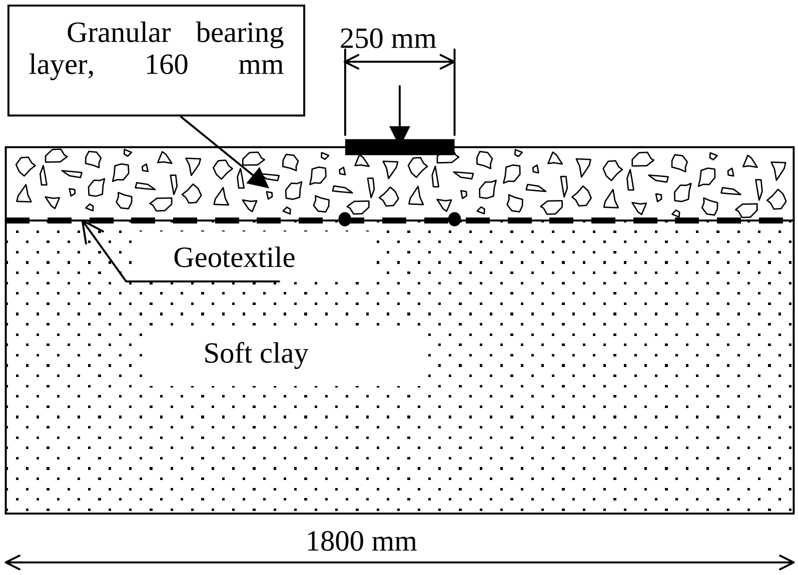

Figure 1 Test set up large scale model test

1.2 *New Norwegian Standard*

Experience from road construction and results from research projects have shown that the current set of requirements is not relevant in all cases. Some of the requirements also tend to disqualify certain types of geotextiles. With the old system woven geotextiles have been excluded from this application in Norway. The European standardisation work performed by CEN TC 189 has provided a number of standards related to required properties and test methods for geosynthetics and at the same time there has been a continuos development of new products and applications. Altogether it was clear that the old classification system had to be revised and extended to include other products and applications.

As a part of the revision of the Norwegian Standard for Specification of construction works it was decided also to develop a new standard for specification of geotextiles. SINTEF was responsible for this part of the standard and the work started in 1994 and the new Norwegian Standard is launched in June 1999. The new standard is based on the experiences gained with the old classification system together with the results from a research project performed at SINTEF.

2 RESEARCH PROJECT

The project focused on the correspondence between geotextile stress-strain properties found in index tests and the observed behaviour in laboratory and field. Based on the experience from the previous classification system the evaluation of relevant deformations and susceptibility for damage was primarily related to the installation and construction phase. The research project included laboratory index testing, large scale model tests and full scale field tests (SINTEF 1996) SINTEF (1997).

2.1 *Large Scale Laboratory tests*

The first project phase (SINTEF 1996) included index tests and large scale laboratory load test. This part aimed to study the correlation between stress-strain properties of non-woven geotextiles found in laboratory index tests and deformations of the geotextiles when subjected to a cyclic loading in a road model. The index tests included cone drop test, static puncture test and wide width tensile test. In addition the effect of thermal cycling and behaviour under frozen conditions were tested.

The large scale laboratory testing was performed in a test bin, 12.5 m long, 1.8 m wide and 0.65 m deep filled with soft clay. The geotextiles were placed on the clay and covered with 150 mm of crushed stone. The principle of the model test is shown in Figure 1.

Static and cyclic loading was than applied on a circular plate with diameter 250 mm on the bearing layer. Deformations of the structure and developed strain of the geotextiles were measured. Some results of measured deformations are shown in Figure 2.

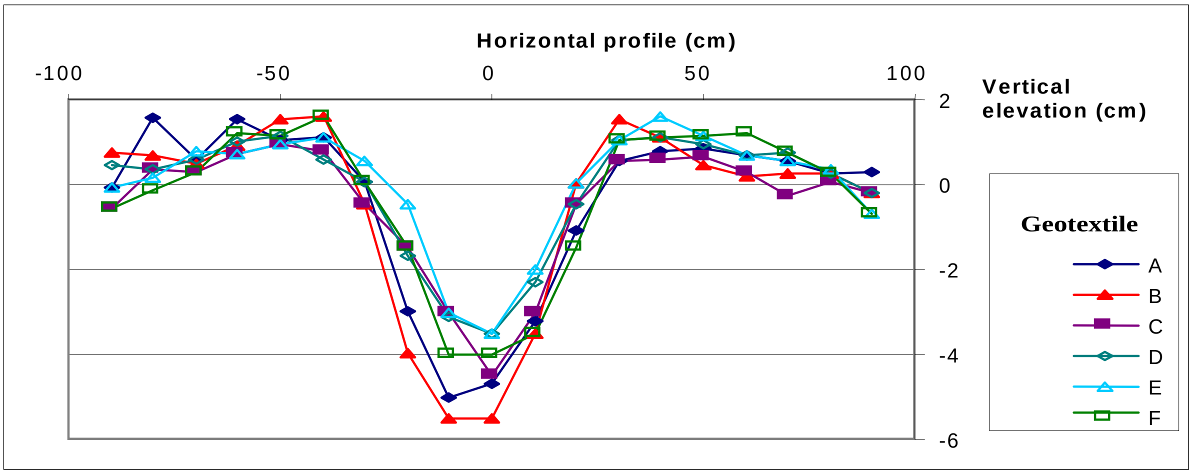

Figure 2 Measured deformation profiles, large scale model test

There are considerable differences in the measured deformations and strains in the load test. The results from the large scale laboratory test indicate that there is a correspondence between the geotextile stiffness and the deformations of the geotextiles when subjected to cyclic loading. Even though the measured deformations and strains were significantly different it was found that the strain energy, that is the integral of the stress-strain curve, related to the measured deformations, were in the same range for all the products.

The test indicates that a requirement on strain energy in combination with stress and strain requirements could be a possible solution.

2.2 *Field test*

The susceptibility to damage is cruicial for the geotextile function and criteria to cover this aspects is clearly needed. The second phase of the research project accordingly was a field test (SINTEF 1997) (5) aiming to study the resistance against damage of the geotextiles during the installation and construction. Geotextiles with different production technology and area weight were used in the research.

2.2.1 *Test set up*

The test was performed outdoor on frozen uneven ground. The material in the ground consists of fill masses with silt, sand, clay and occasional stones. Due to rainfall just before and under the installation the upper 50-100 mm of the underground was saturated and muddy during the installation. As the temperature was decreasing during the test, this upper layer was frozen at the time of the extraction. The installation of fill material in the field test is shown on Figure 3. The geotextiles were placed directly on the ground and then covered with fill material by the use of a pay loader. The fill material was compacted with a heavy vibrating roller with three overpasses along the centre line and on the shoulders on top of each fill. One week after the installation the fill material was removed. The top of the fill material was removed carefully with an excavator. The geotextile was then tied to the excavator and carefully lifted out.

2.2.2 *Test results*

After extraction the samples were brought to the laboratory where the damage (number and size of holes) where counted and measured. There was significant difference in the amount of damage between the different geotextiles tested.

Figure 3 Full scale field test.

2.2.3 *Test results*

In order to correlate the observed damage with index test results the degree of *Damage* on a geotextile is defined as the sum of the measured hole diameters. The *Resistance against damage* for one product can then be defined as the average damage divided by the damage on each geotextile as shown in Table 1, that is, the higher number the less damage. In the table the measured damage is normalised with respect to the average value for the five geotextiles, that is, a factor of 1.15 means 15 % less damage than the average.

Table 1 Evaluation of damage from field test

Reference.	Area weight *(g/m^2)*	Damage (Sum of hole diameter)	Resistance against damage (Average damage)/ damage)
F	320	2793	1.07
G	330	2613	1.15
H	320	3157	0.95
I	350	2655	1.13
J	300	3759	0.80
K	350	Separate test	0.40*)

**) Based on a scaling of the results*

2.2.4 *Evaluation of results*

The resistance against damage and the results from the index tests are used to evaluate the requirements in the old classification system. The relevancy of an index test parameter for survivability of the geotextile is studied by correlating the parameter with the *resistance against damage* as defined above. The area weights are also included in the correlation. The parameters showing best correlation with the resistance against damage is the *push through strength* and the *area weight.* The criteria for *strength increase*, and *the number of points* show poor correlation. The *strain to failure* and the *cone drop hole diameter* show a fair negative correlation. It must however be remarked that these results were based on geotextiles that all have a relatively high elongation at failure, more than 50%. The poor correlation for the number of points, which is the basis for classification in the old system, is remarkable. The low correlation is mainly caused by the fact that two of the geotextiles with most damage have full score based on the criteria in the index test. The results from the index test do not point out an obvious candidate among the parameters that may explain why geotextile K should be so severely damaged. This geotextile has a relatively low value both for *strain to failure* and the *inverse of the cone drop hole diameter*. These low values may partly explain some of the higher degree of damage for the geotextile K.

The test clearly shows that requirements related to susceptibility to damage are needed. It also shows that the survivability criteria used in the old system, strength increase from 20-70% strain, does not seem to reflect what can be observed in the field. It was however found that there was a correlation between the susceptibility to damage and strain energy of the geotextile. The strain energy is based on the wide with tensile test, average between machine and crossways direction for the maximum tensile stress and the corresponding strain at the maximum stress. The observed damage from the field test and the strain energy is shown in table 2. The geotextiles A-E has been tested in the field test with granular material 0-60 mm (related to original application class II), while the geotextiles F-K have been tested with granular material up to 500 mm (application class IV).

Table 2 Observed damage from field test

Ref	Area Weight *(g/m²)*	Type of product *)	Calculated strain energy (kN/m)	Observed damage
A	110	CF, NP	1.8	Some
B	145	SF, NP	4.5	Little
C	140	SF, NP	1.5	Some
D	136	CF, TB	2.4	Little
E	120	CF, TB	0.9	Severe
F	320	CF, NP	8.1	Little
G	360	SF, NP	9.5	Little
H	320	SF, NP	4.8	Some
I	300	CF, TB	4.7	Little
J	350	SF, NP	7.2	Some
K	350	CF, TB	3.2	Considerable

*) CF: Continous fibre, SF, Staple fibre
NP: Needle punched, TB: Thermal bonded

3 REQUIRED PROPERTIES

The new standard required the development of a new set of criteria for geotextiles for separation and filtration in roads. It was decided to develop specification profiles related to the applications with corresponding criteria related to mechanical properties and hydraulic properties.

3.1 *Mechanical properties*

The mechanical properties should reflect the requirements related to the installation and service lifetime. The experiences from the field combined with the results from the research project verify that the possibility for mechanical damage is primarily related to the installation and construction phase. Similar to the original classification system it was decided to include requirements related to tensile stress and strain. The basic idea is that after the installation and construction phase a certain reserve of stress and strain should be intact to cover for the function during the service lifetime. In the original classification system the requirements on stress-strain properties were based on calculated values based from the CBR-test. The calculation of stress and strain from the CBR-test is based on certain assumptions of the deformation and the strain distribution in the geotextile. The result of these calculations may vary significantly with the geotextile properties and a comparison of results between geotextiles with different stress-strain properties based on the CBR-test accordingly may be misleading. It was therefore decided to base the evaluation of stress-strain properties on the wide width tensile test as defined in the European standard. The resulting criteria on minimum stress and strain are based on the average from machine and crossways direction.

The test results show a close correspondence between the stiffness of the geotextile and the deformations developed during installation and compaction of the fill. A stiff geotextile will however mobilise higher tension than a softer geotextile. The strain energy varies less than the variations in strain and tension between different types of geotextiles. A strain energy requirement was therefore regarded to be well suited to cover geotextiles for a wide range in stress-strain properties. It is assumed that a certain level of strain energy is related to the installation and construction phase and that a reserve in strength and strain should be available for the service lifetime. The principle is shown in Figure 4.

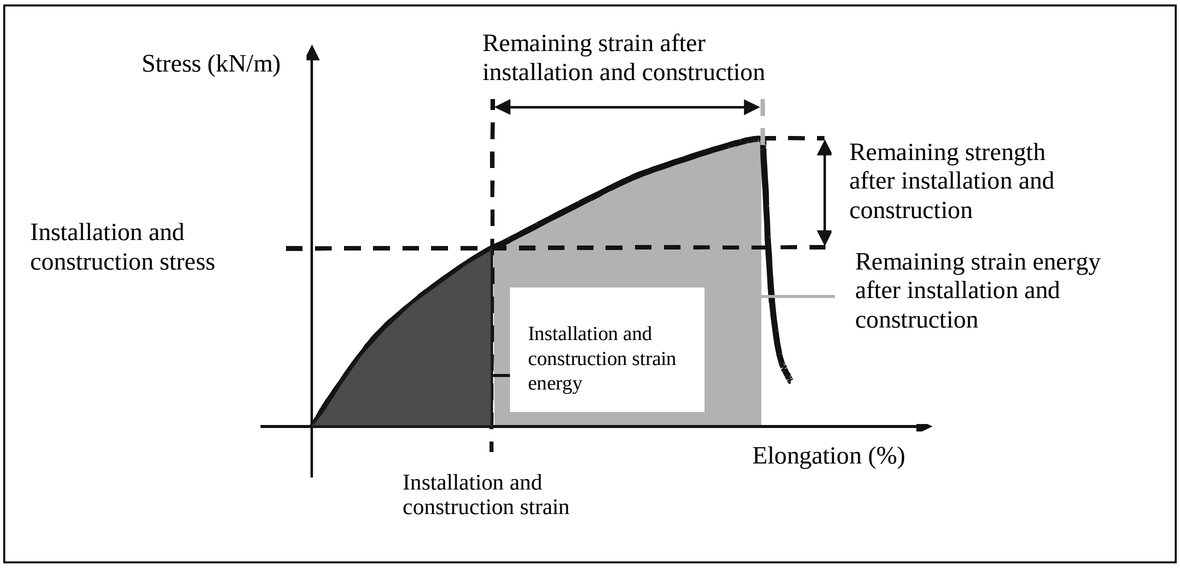

Figure 4 Principle figure. Stress, strain and energy relationship

A criterion based on strain energy combines stiffness, failure strain and failure stress in one criterion. As basis for the criterion the wide width test is preferred because a large number of data with test results is available for various types of geotextiles, even though a three dimensional test like the CBR-test may better reflect the situation in the field. Different principles have been discussed for how to calculate the strain energy. In order to make the use of the criterion as simple as possible the energy criterion is calculated as: (maximum tension) x (the corresponding strain) x 0.5, as shown in Figure 5.

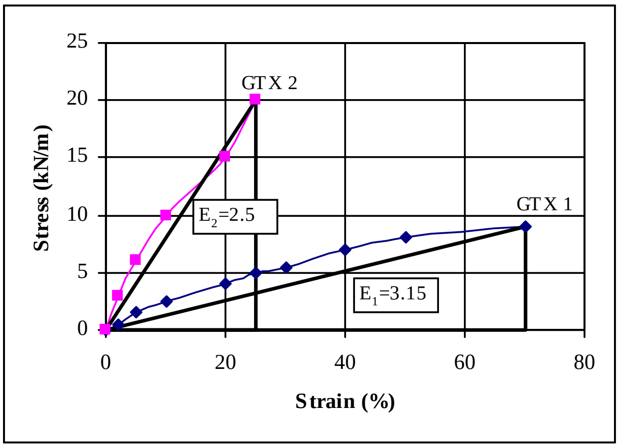

Figure 5 Calculation of strain energy

It was also decided to include requirements related to the properties found from the cone drop test. The original classification system had requirements based on this test method and the experiences from nearly 30 years using this criteria have been taken into account. This requirement is intended to cover for the possibility of puncturing of the geotextile likely to occur e.g from sharp stones pentrating the geotextile on soft subsoil. The final requirements are mainly based on the experiences from the original classification system but is also correlated with the results from the field test in the research project.

3.2 *Hydraulic properties*

Geotextiles used for separation and filtration in roads basicly fulfill a separating function. However as water is always present in this type of structure the geotextile also have to fulfill a filtration function. The filtration conditions commonly are not particularly severe, gradients and water flow are generally low, but the geotextile filtration function should be fulfilled for a considerable time for the service life. During the installation and construction the filtration properties may be changed due to mechanical damage and during the service lifetime the properties may change due to long term effects. Both aspects have to be taken into consideration for the evaluation of relevant requirements on hydraulic properties. The field experiences indicated however that relatively simple hydraulic requirements were sufficient to fulfill the filtration function for this application provided that mechanical damage was avoided. The final requirements accordingly only included requirements on opening size, O_{90}, and permability of the geotextile based on the standardized European test methods. It is however pointed out that these “rule of thumb” requirements are only to be used when the hydraulic conditions are relatively simple and that a specific hydraulic design is required for more severe conditions.

4 SPECIFICATION SYSTEM

The specification of geotextiles for separation and filtration in roads was decided to be based on a set of requirements general for all applications combined with specification profiles related to this specific application. The system also includes requirements on quality control of the product, both for the product characteristics itself and for quality control on site.

4.1 *General requirements*

The general requirements are based on the standards for general and specific requirements, which are under preparation by CEN TC 189. These standards give requirements related to identification of the product, which properties should be documented for the products and the corresponding standardized test method to be used. In addition the Norwegian standard gives some general requirements related to durability, resistance to mechanical damage, storage and handling.

4.2 *Specification profile*

The specification profiles provides a set of requirements related to mechanical and hydraulic properties of the products. As presented in chapter 3 the specification profiles are based on requirements on:

S: tensile strength at failure
E: tensile elongation at failure
C: hole size from cone drop test
R: strain energy calculated from tensile test
I: permeability in the cross way direction
J: characteristic opening size

The figures for each specification profile related to these characteristic properties are given in table 3.

Table 3 Specification profile

Profile	Required characteristics					
	S kN/m	E %	C mm	R kN/m	I 10^{-4} m/s	J mm
S1	>7	>25	<40	>1	>1	<0.15
S2	>12	>35	<25	>3	>1	<0.15
S3	>20	>50	<18	>5.5	>1	<0.15
S4	>30	>50	<12	>7.5	>1	<0.15
F1	>5	>15	<45	>0.7	>5	<0.2
F2	>10	>15	<30	>2.5	>5	<0.2
F3	>20	>20	<20	>5	>5	<0.2
F4	>30	>30	<12	>7	>5	<0.2

It should be noted that the specification profiles do not distinguish between different type of products as the requirements are the same independent of the type of product.

4.3 *Selection of specification profile*

The selection of the relevant specification profile is based on the following input:

-subsoil conditions
-maximum grain size of fill material
-construction equipment and procedures

The subsoil conditions are divided into two categories: soft and firm subsoil. Soft subsoil is typically clay, silt or peat with and undrained shear strength less than 25 kN/m^2. Firm subsoil is typically moraine, stiff clay, sand and gravel. The construction equipment and procedures are divided into two categories: Normal and severe where severe is related to the use of thin compaction layers or heavy vibrating equipment. The selection of relevant specification profile is then based on the combination given in table 4.

Table 4 Selection of specification profile

Subsoil	Max diameter, fill material (mm)	Construction	
		Normal	Severe
Soft	<60	S1	S2
	60-200	S2	S3
	200-500	S3	S4
	>500	S4	S4
Firm	<60	F1	F2
	60-200	F2	F3
	200-500	F3	F4
	>500	F4	F4

The combination of the specification profiles and the selection tables thus provides a linking between the site- and construction conditions and a set of required geotextile properties. The specifier may of course, based on his own judgement, choose a specification profile independent on the recommendations in table 4.

4.4 *Quality control*

The standard also includes requirements related to the quality of the product. The quality control is performed at two levels:
-variation of product characteristics
-control of products on site

4.4.1 *Variation of product characteristics*

Laboratory testing and field experiences indicated that there may be significant variations of the product characteristics. The field experiences also indicated that these variations are crucial for the function of the product. Accordingly it was decided to put requirements on maximum variance of some selected characteristics. The requirements are set as maximum standard deviation of the results from standardized test methods as given in table 5.

Table 5 Requirements on standard deviation

Characteristic	Test method	Maximum standard deviation
Mass per unit area	EN 965	10%
Tensile strength	EN-ISO 10319	10 %
Tensile strain	EN ISO 10319	20%
Opening size	EN ISO 12956	30%

4.4.2 *On site control*

The specification system also includes requirements for on site control of the products. The characteristics to be tested for the field control are mass per unit area and either tensile strength from the wide width tensile test or maximum force from the CBR-test. The acceptance levels for the quality control are related to the nominal values as follows:
Mass per unit area: nominal value +/- 10%
Tensile strength: nominal value –10%
Maximum CBR-force: nominal value –10%
A minimum of one test per first 5000m^2 and then one test per each 20.000m^2 is required.

5 EXPERIENCES

The new specification system has now been in use for nearly one year. A revision of the system is planned to take place within two years after the introduction and a collection of experience from the use of the system has been started. Since the system only has been in use for a short time the experiences are limited but some preliminary results can be found.

The general layout of the system with the specification profile and the linking to the site conditions seem to work well. There seem though to be a need for some more flexibility in the specification in terms of changing some of the required characteristic in a specification profile. This is specifically related to the requirement on minimum tensile stress and strain at failure.

The system for quality control has so far not been taken into use according to the intentions. This is partly because of a lack of knowledge among the users but also partly because in Norway there is no certification system and accordingly there are no clear responsibility for the testing and also no clear consequences of the quality control testing.

6 FURTHER WORK

There is already started a project on harmonization of the specification systems for geotextiles for separation and filtration in roads in the Nordic countries. The project is aiming at a common system for specification and quality control of the product in Finland, Sweden and Norway. The conditions, in terms of subsoil and climate in these three countries, are relatively similar and a common system would be beneficial both from a technical and commercial point of view.

The project is intended to evaluate the experiences with the existing systems. On this basis it is planned both to consider possible need for additional tests and required characteristics and for a revision of the figures with the existing requirements. The revision of the Norwegian standard is planned to be coordinated with this work.

The project is also intended to evaluate the need for a common Nordic system for quality control of the products. There is currently work going on by CEN TC 189 on the development of a common European system for on site quality control and the need for a specific Nordic system will be dependent of the outcome of this work.

7 CONCLUSIONS

The new Norwegian standard for specification of geotextiles for separation and filtration of roads is based on specification profiles with requirements on tensile strength, tensile strain, strain energy, hole size from cone drop test, permeability and characteristic opening size. The system is based on experiences form the old classification system combined with results from a research project including laboratory testing, model tests and field tests.

The selection of relevant specification profile is based on an evaluation of the subsoil, fill material and construction equipment and procedures for the specific project.

The system also includes requirements on quality control of the product properties and for control on site. So far the experiences with the new system are good. Some changes of the required characteristics for some of the figures could though be beneficial. A revision of the system is planned as a part of the development of a common Nordic system for specification of geotextiles for this application.

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