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National European specifications and the energy concept

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ABSTRACT: Recently several European national specifications or classifications for geotextiles have been renewed. In one or the other way the energy absorption potential of a geotextile is nowadays considered a property worth incorporating into national European norms. As test research from independent institutes as well as DuPont de Nemours demonstrates, there is a correlation between the resistance of a geotextile to installation stresses and its energy absorption potential. The common reference properties for specifying a geotextile, such as tensile strength or static puncture resistance, do not necessarily reflect the product's performance during installation. The importance of installing a geotextile that will resist possible damages during installation has been recognised.

1 INTRODUCTION

A geotextile can fulfil a variety of functions, many of them in combination such as separation and filtration, but also reinforcement or protection functions. The foremost requirement though is its resistance against damage. A damaged geotextile will not be able to perform any function. The most critical phases in the life of a geotextile is the installation and construction phase rather than the service life. Generally the geotextile will withstand the service stresses if it has survived the construction-induced stresses.

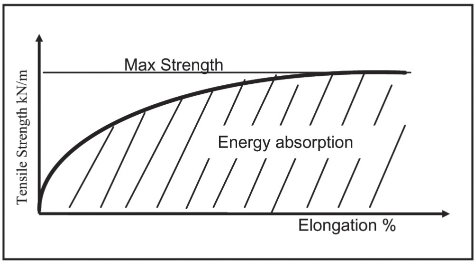

Figure 1. Energy absorption potential W of a geotextile according to EN ISO 10319.

1.1 *The energy absorption concept*

Like any other material a geotextile has a certain energy absorption potential. For geotextiles the energy absorption is defined as the area under the stress-strain curve for tensile strength (Fig. 1). The energy absorption [kJ/m^2] is the maximum energy a geotextile can absorb before failure. In some norms and specifications reference is made to an index (i.e. Energy absorption index, indice de comportement mécanique), which is determined by multiplying maximum strength and using an approximate method to determine the energy absorption level instead of the energy absorption potential.

SINTEF (Watn and Eiksund 1997) performed a research project on the mechanical damage of geotextiles during installation including field tests with a number of nonwoven geotextiles and concluded that the energy absorption of geotextiles is an important factor in the determination of damage resistance.

1.2 *Norms, specifications and classification systems*

Some 25 years ago when geotextiles were specified, this was frequently done by weight per unit area or by "brand name XXX or equivalent". Further properties of the geotextile were determined by applying test methods for textile fabrics. With time and experience many countries developed more appropriate testing methods, national specifications and classification systems.

In 1977 the Norwegian Road Research Laboratory (Alfheim and Sørlie 1977) introduced such a system, followed by the French recommendations by the CFG (Comité Française Géosynthétiques) in 1981, which took the approach of specifying several properties depending on the type of structure (e.g. light or heavy traffic roads, parking areas,…) and taking into account the site conditions (bearing capacity of the supporting ground) and the materials used in the structure (nature and thickness of the fill material).

In Germany a multitude of experimental field and laboratory tests were conducted (Bräu 1993) which served as the basis for the German classification system (FGSV 1994). A similar approach was adopted in the USA and a classification system was introduced by AASHTO (1996).

2 INSTALLATION DAMAGE TESTS

After studying/participating in the tests performed by SINTEF a new improved test methodology has been developed by DuPont de Nemours in order to analyse the behaviour of geotextiles under field conditions. This repeatable method allows a controlled installation of the geotextile for testing and protects the sample from further damage during the extraction phase. The conditions were intentionally severe to ensure the damage of all geotextiles, thus providing data for comparison and evaluation after extraction.

2.1 *Product selection and properties*

A range of commonly used geotextiles for separation applications was selected to be tested for the evaluation of the field performance. They differed in manufacturing process technologies, weights and mechanical properties. The following products were selected:

- 5 woven tape products
- 2 nonwoven products: needle-punched, continuous fiber
- 2 nonwoven products: thermally bonded, continuous fiber (PP/PET), low elongation properties (manufacturer A)
- 5 nonwoven products: thermally bonded, continuous (PP) with high elongation properties (manufacturer B)

To allow an evaluation of the most commonly required properties, the corresponding standard index tests were performed on each geotextile before the testing (Table 1a, 1b). Properties such as tensile strength, puncture resistance and unit weight have long been regarded as such key parameters. The evaluation of the damage tests provided the correlation these properties actually have to the resistance against damage during installation.

2.2 *Test set up*

As the basis for the test steel plates (2 × 2.5 m) were used. Steel chains were welded on two corners for the extraction. On top of the plates a soft clay subgrade from the local site was placed and compacted to a thickness of 25 cm. A geotextile sample (2 × 2 m) was laid directly on the subgrade and covered with a layer (25 cm) of high furnace slag (40-60 cm diameter), which was dropped from a height of 50 cm on the geotextile. Then the system was compacted with a 7-ton vibratory roller (4 passes, forward and backward).

To extract the geotextile the steel plate with the soil/geotextile/aggregate system on top was tilted and then lifted. The aggregate slid off the geotextile, so avoiding additional damage to the geotextile. All geotextiles were installed and extracted under identical conditions.

2.3 *Evaluation of test results*

After cleaning the samples, the edges (25 cm) were removed, and the remaining surface area (1.50 × 1.50 m) was analysed in the laboratory. The number and diameter of the holes was measured and used to determine the total damaged surface area (%) of each sample.

A 1.5 × 1.5 m template with a pre-determined pattern was placed on each sample in order to cut 10 specimen in both machine and cross direction. Using this pattern ensured that the same area of each geotextile sample was used to evaluate the remaining tensile strength after extraction.

2.4 *Discussion of results*

The correlation of the total damaged surface area (%) with all of the index tests was compared.

A good correlation has been observed between the damaged surface area and retained strength (Fig. 2).

Unit weight (Fig. 3) and thickness (Fig. 4) are descriptive properties and do not provide any information relating to performance when comparing different products. Only for products of the same "family" (i.e. manufactured according to the same process), the damage resistance is directly related to the uniform spread of its unit weight. At a uniform external stress, it is the weakest parts of the geotextile, which are the first to be damaged, therefore a uniform unit weight or thickness over the width of the product can be an indicator for the quality of a product.

For specification purposes, average unit weight and thickness are however irrelevant, since the unit weight to achieve a given performance depends on the different manufacturing technique.

No correlation was identified between the damage and any of the mechanical properties such as tensile strength, CBR puncture resistance, grab tensile strength and tear resistance (Fig. 5-8).

Although dynamic puncturing (Cone Penetration, Fig. 10) is usually regarded as a performance test simulating real conditions rather than an index test, little correlation has been observed during this test.

Table 1a and 1b. Chosen products and measured properties (before testing).

Property	Standard	Unit	Woven Tape Geotextiles				
Area Weight	EN 965	g/m^2	86	146	87	177	109
Thickness	EN 964-1	µm	432	685	447	923	480
Tensile strength MD	EN 10319	kN/m	18	30	12	26	23
Tensile strength XD			12	26	11	27	17
Avg.			15	28	11	27	20
Elongation MD	EN 10319	%	23	32	14	43	24
Elongation XD			20	22	9	31	16
Avg.			22	27	11	37	20
Energy Abs. MD	EN 10319	kN/m	2.5	5.9	1.0	6.8	3.2
Energy Abs. XD			1.2	3.4	0.6	5.6	1.7
Avg.			1.8	4.6	0.8	6.2	2.5
CBR	EN 12236	kN	1.12	3.02	0.73	2.26	1.91
Cone Penetration	EN 918	mm	16	12	27	11	16
Grab MD	ASTM D4632	N	634	1055	511	1012	757
Grab XD			378	709	411	864	488
Avg.			506	882	461	938	623
Trap Tear MD	ASTM D4533	N	281	388	241	484	252
Trap Tear XD	ASTM D4533	N	201	365	203	672	254
Avg.			241	377	222	578	253

Property	Needlepunched cont. fibres		Th.B. "A" PP/PE		Th. B. "B" PP				
Area Weight	114	155	113	133	91	111	127	137	168
Thickness	937	1254	737	753	393	389	416	442	485
Tensile strength MD	8	13	6	8	4	8	8	8	11
Tensile strength XD	8	13	6	11	6	7	9	9	13
Avg.	8	13	6	10	5	8	8	9	12
Elongation MD	85	105	19	23	31	53	44	41	53
Elongation XD	74	48	18	24	50	53	52	47	54
Avg.	80	76	18	23	41	53	48	44	53
Energy Abs. MD	3.7	7.8	0.8	1.4	1.1	3.4	2.8	2.7	4.8
Energy Abs. XD	3.2	3.8	0.7	1.7	2.2	2.9	3.5	3.2	5.3
Avg.	3.5	5.8	0.7	1.5	1.7	3.2	3.1	2.9	5.1
CBR	1.35	1.87	1.00	1.64	0.72	1.23	1.26	1.30	1.75
Cone Penetration	29	29	43	36	48	33	30	26	24
Grab MD	522	719	422	726	381	644	677	707	997
Grab XD	504	646	393	596	428	608	662	717	1035
Avg.	513	683	408	661	405	626	670	712	1016
Trap Tear MD	263	406	224	335	188	330	310	390	459
Trap Tear XD	267	312	220	362	235	266	292	370	366
Avg.	265	359	222	349	212	298	301	380	412

Table 2. Evaluation of damaged area and retained strength.

	Woven Tape Geotextiles				Needlepunched cont. fibres		
Damaged area							
Holes total surface m^2	0.157	0.020	0.126	0.002	0.082	0.007	0.004
sample surface m^2	2.25	2.25	2.25	2.25	2.25	2.25	2.25
% damaged surface	6.97	0.88	5.59	0.07	3.65	0.31	0.17
% Retained Strength							
MD	43	62	56	100	77	80	79
XD	95	85	79	94	70	85	78
Avg:	62	73	67	97	74	82	78

	Th.B. "A" PP/PE		Th. B. "B" PP				
Damaged area							
Holes total surface m^2	0.096	0.200	0.072	0.011	0.016	0.005	0.006
sample surface m^2	2.25	2.25	2.25	2.25	2.25	2.25	2.25
% damaged surface	4.29	8.89	3.20	0.47	0.71	0.23	0.28
% Retained Strength							
MD	50	60	75	68	72	74	76
XD	48	39	60	93	74	90	87
Avg:	49	48	67	80	73	82	82

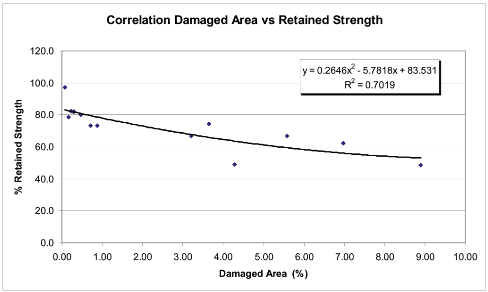

Figure 2. Correlation between damaged area and retained strength.

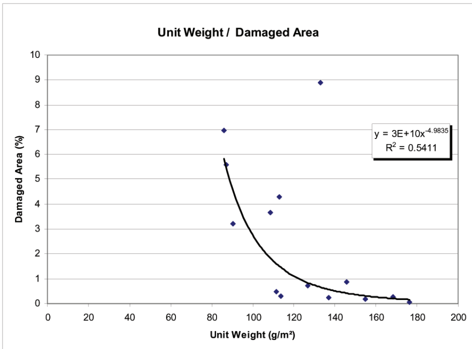

Figure 3. Correlation of damaged area with unit weight.

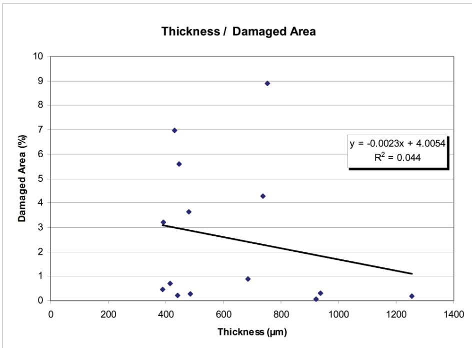

Figure 4. Correlation of damaged area with thickness.

Excellent correlation has been found between the damaged area and the energy absorption (defined as the area under the stress-strain curve determined according to EN ISO 10319, Fig. 9).

Under the used test conditions it is clearly seen that all geotextiles with an energy absorption of less than 3 kN/m have shown significant damage, whereas those geotextiles with an energy absorption greater than 3 kN/m survived these conditions without major damage.

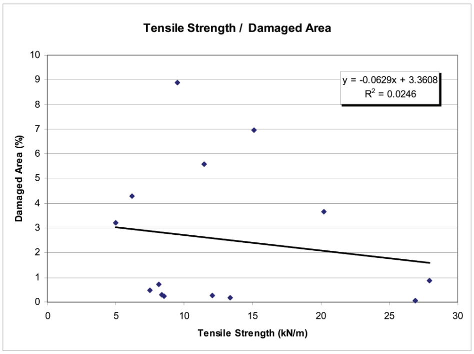

Figure 5. Correlation of damage area with tensile strength.

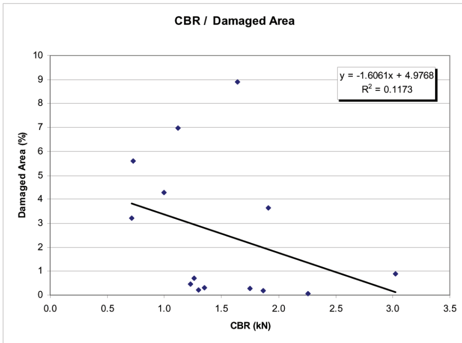

Figure 6. Correlation of damaged area with puncture strength.

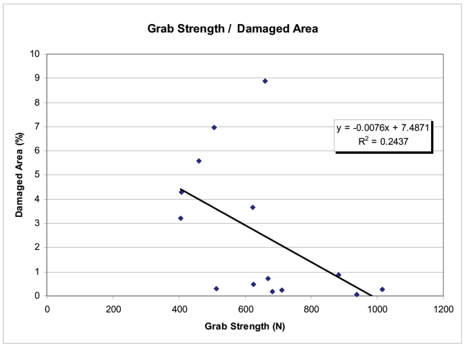

Figure 7. Correlation of damaged area with grab strength.

2.5 *Conclusion*

The project provided useful information for evaluating the relevant properties and requirements for geotextiles to avoid damage during installation. The results showed that most properties used in several specification and classification systems do not reflect the behaviour in the field and supports the approach

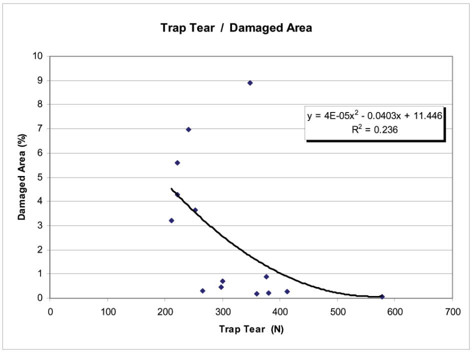

Figure 8. Correlation of damaged area with tear strength.

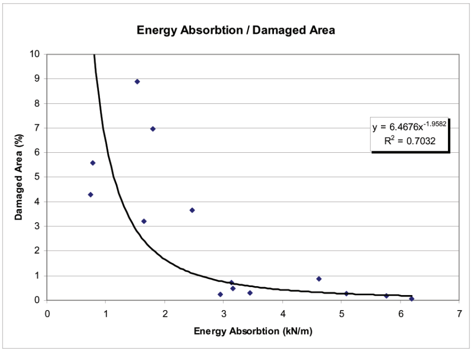

Figure 9. Correlation of damaged area with energy absorption.

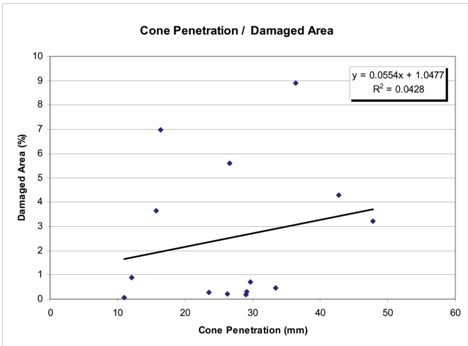

Figure 10. Correlation of damaged area with cone penetration.

taken by different countries to include the energy absorption into their classification systems.

A clear correlation between energy absorption and damage resistance has been found for all geotextiles tested, independent of their manufacturing process and physical structure.

A common criteria based on the energy absorption principle allows the specifier to select the appropriate product performance depending on the different applications and site conditions.

The test method developed allows a rapid and precise damage evaluation of geosynthetics and may be used as a basis for further determining performance related criteria.

3 INTEGRATION OF THE ENERGY ABSORPTION IN NATIONAL EUROPEAN CLASSIFICATIONS

Some classification systems already consider the combination of both strength and elongation properties. For example, the German classification system differentiates between woven geotextiles, which generally have a low elongation, and nonwoven geotextiles. The AASHTO M288-96 classification requires higher mechanical properties for geotextiles of lower elongation and sets the limit empirically at a 50% elongation.

3.1 *France*

A recent recommendation for a new French classification has been proposed by J.C. Blivet in 1999 and is still under discussion.

The proposal also takes into account the energy concept as the main criteria for the specification of all geotextiles.

The principle of the French recommendation is to use a minimum strength at 50% elongation, the so-called Index of Mechanical Behaviour (indice de comportement mécanique, ICM) but allows compensating lower elongation by higher strength (Fig. 11). As a result, products with the same energy absorption or same damage resistance are specified rather than products with e.g. similar tensile strength but different behaviour under stress.

3.2 *Norway and Switzerland*

The new Norwegian standard NS 3420-13 (1999) and the Swiss standard SN 640 552 (1997) both define

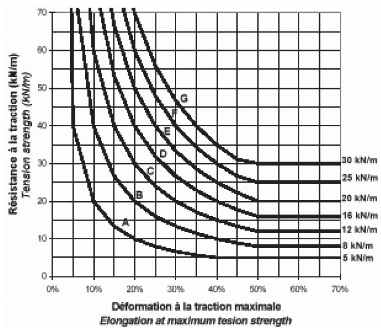

Figure 11. French energy absorption concept proposal: J.C. Blivet, Rencontres Bordeaux 1999.

the energy absorption capacity of a geotextile as half of the product of the tensile strength multiplied by the elongation at maximum load, which is a simplified approach.

The Norwegian, Finnish and Swedish Road Administrations have together developed a Nordic specification system (NorGeoSpec) based on the seven characteristics measured with test methods defined by CEN and ISO. The NorGeoSpec incorporates the energy absorption potential as one of the criteria. It is called strain energy index.

3.3 *Europe*

Instead of defining the absorbed energy as the area under the stress-strain curve, the Norwegian, Swiss and French proposals, all take a simplified approach (1, 2, 3) and define energy absorption as the product of tensile strength (T) and elongation (ε_f) at maximum strength.

$$^1/_2 * F_a * \varepsilon_a = R_a \text{ or } W_i \qquad \text{(NorGeo)} \qquad (1)$$

$$T * \varepsilon = R \qquad \text{(Switzerland)} \qquad (2)$$

$$^1/_2 * T * 50\% = ICM \qquad \text{(France)} \qquad (3)$$

In order to differentiate between the actual and simplified energy absorption potential and in order to avoid confusion around this new property, the definition was added in European norm EN ISO 10318. Here the energy absorption W is defined as the area under the stress-strain curve for tensile strength and the energy absorption index W_i as described above.

In a further effort on a European level, the proposal for a new working item will be made to define the measurement of the energy absorption potential as a separate standard.

The new European standard prEN 13249: « Required characteristics for geotextiles and geotextile-related products used in the construction of roads and other trafficked areas », requires for the separation function following characteristics: Tensile strength, elongation at maximum load, static puncturing (CBR), dynamic perforation and resistance to damage during installation. A recently developed European laboratory standard test method aiming to simulate quantitative damage during geotextile installation is currently being evaluated (Khay 1998).

4 CONCLUSIONS

Research tests from independent institutes and DuPont de Nemours demonstrate the importance of the high energy absorption potential of a geotextile. Research in different European countries as well as in the USA has led to the incorporation of energy absorption or the combination of tensile strength and elongation requirements into specifications and classification systems. Energy absorption has commenced to be widely recognised as the significant property in the selection process of a geotextile.

The final version of the new French classification is strongly anticipated as well as the revision of EN ISO 10319.

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