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THE ENERGY ABSORPTION POTENTIAL AND ITS INTEGRATION IN THE NATIONAL EUROPEAN SPECIFICATIONS

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The energy absorption potential of a geotextile is nowadays considered a property worth incorporating into national European norms. As the research from independent institutes and DuPont de Nemours demonstrate, there is a correlation between the resistance of a geotextile to the 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 always reflect the product performance during installation. The importance of installing a geotextile that will resists possible damages during installation has been recognized.

Key words: energy absorption, damage resistance, damage during installation, geotextiles, installation

1. INTRODUCTION

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

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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 a reference is made to an index which is determined through an approximation method to determine the energy absorption level instead of the energy absorption potential.

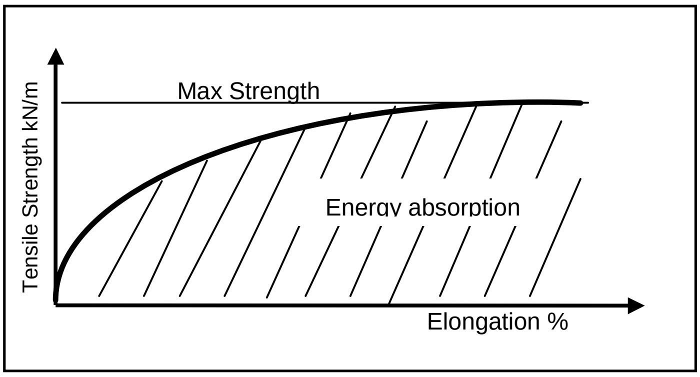

Fig. 1: Stress-strain curve – Tensile Strength

SINTEF [1] performed a research project on the mechanical damage of geotextiles during installation including field tests with a number of non-woven 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 [2] introduced such a system, followed by the French recommendations by the CFG [3] 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 [4] were conducted which served as the basis for the German classification system

[5]. A similar approach was adopted in the USA and a classification system was introduced in 1990 by AASHTO [6].

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 analyze the behavior 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 non-woven products: needle-punched, continuous fiber
- 2 non-woven products: thermally bonded, continuous fiber (PP/PET), low elongation properties (manufacturer A)
- 5 non-woven 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 1). 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

Steel plates (2 x 2.5 m) were used as the basis for the test. 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 x 2 m) was laid directly on the subgrade and covered with a layer (25 cm) of high furnace slay (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, thus avoiding additional damage to the geotextile. All geotextiles were installed and extracted under identical conditions.

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

Property	Standard	Unit	Woven Tape Geotextiles					Needlepunched cont. fibres		Th.B."A" PP/PE		Th.B."B" PP				
Area Weight	EN 965	g/m²	86	146	87	177	109	114	155	113	133	91	111	127	137	168
Thickness	EN 964-1	µm	432	685	447	923	480	937	1254	737	753	393	389	416	442	485
Tensile strength MD	EN 10319	kN/m	18	30	12	26	23	8	13	6	8	4	8	8	8	11
Tensile strength XD			12	26	11	27	17	8	13	6	11	6	7	9	9	13
Avg.			15	28	11	27	20	8	13	6	10	5	8	8	9	12
Elongation MD	EN 10319	%	23	32	14	43	24	85	105	19	23	31	53	44	41	53
Elongation XD			20	22	9	31	16	74	48	18	24	50	53	52	47	54
Avg.			22	27	11	37	20	80	76	18	23	41	53	48	44	53
Energy Abs. MD	EN 10319	kN/m	2.5	5.9	1.0	6.8	3.2	3.7	7.8	0.8	1.4	1.1	3.4	2.8	2.7	4.8
Energy Abs. XD			1.2	3.4	0.6	5.6	1.7	3.2	3.8	0.7	1.7	2.2	2.9	3.5	3.2	5.3
Avg.			1.8	4.6	0.8	6.2	2.5	3.5	5.8	0.7	1.5	1.7	3.2	3.1	2.9	5.1
CBR	EN 12236	kN	1.12	3.02	0.73	2.26	1.91	1.35	1.87	1.00	1.64	0.72	1.23	1.26	1.30	1.75
Cone Penetration	EN 918	mm	16	12	27	11	16	29	29	43	36	48	33	30	26	24
Grab MD	ASTM D4632	N	634	1055	511	1012	757	522	719	422	726	381	644	677	707	997
Grab XD			378	709	411	864	488	504	646	393	596	428	608	662	717	1035
Avg.			506	882	461	938	623	513	683	408	661	405	626	670	712	1016
Trap Tear MD	ASTM D4533	N	281	388	241	484	252	263	406	224	335	188	330	310	390	459
Trap Tear XD	ASTM D4533	N	201	365	203	672	254	267	312	220	362	235	266	292	370	366
Avg.			241	377	222	578	253	265	359	222	349	212	298	301	380	412

2.3. Evaluation of test results

After cleaning the samples, the edges (25 cm) were removed, and the remaining surface area (1.50 x 1.50 m) was analyzed 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 x 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.

Table 2. Evaluation of the damaged area and the retained strength

	Woven Tape Geotextiles					Needlepunched cont. fibres		Th.B."A" PP/PE		Th.B."B" PP				
Damaged area														
Holes total surface m²	0.157	0.020	0.126	0.002	0.082	0.007	0.004	0.096	0.200	0.072	0.011	0.016	0.005	0.006
sample surface m²	2.25	2.25	2.25	2.25	2.25	2.25	2.25	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	4.29	8.89	3.20	0.47	0.71	0.23	0.28
% Retained Strength														
MD	43	62	56	100	77	80	79	50	60	75	68	72	74	76
XD	95	85	79	94	70	85	78	48	39	60	93	74	90	87
Avg :	62	73	67	97	74	82	78	49	48	67	80	73	82	82

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 the retained strength (Fig. 2).

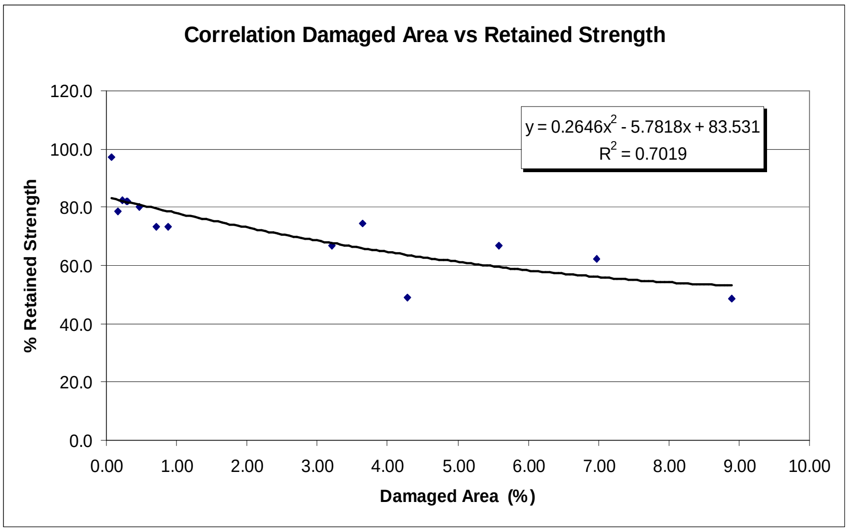

Fig. 2: Correlation between the damaged area and the retained strength

Unit weight (Fig. 3) and thickness (Fig. 4) are descriptive properties and do not provide any information related 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. However, as the dropping height in the trial was limited to 50 cm, the cone penetration test may have a higher significance as the aggregate dropping height increases.

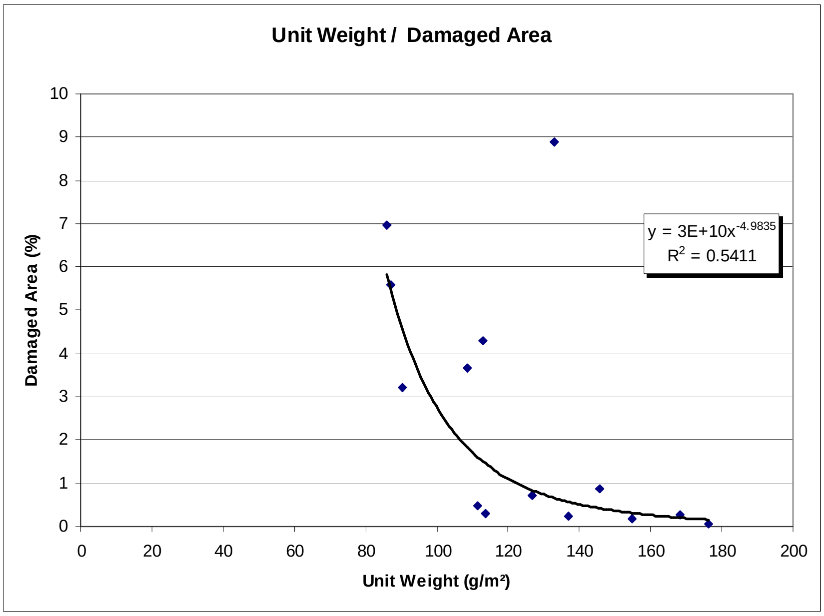

Fig. 3: Correlation with Area/Weight

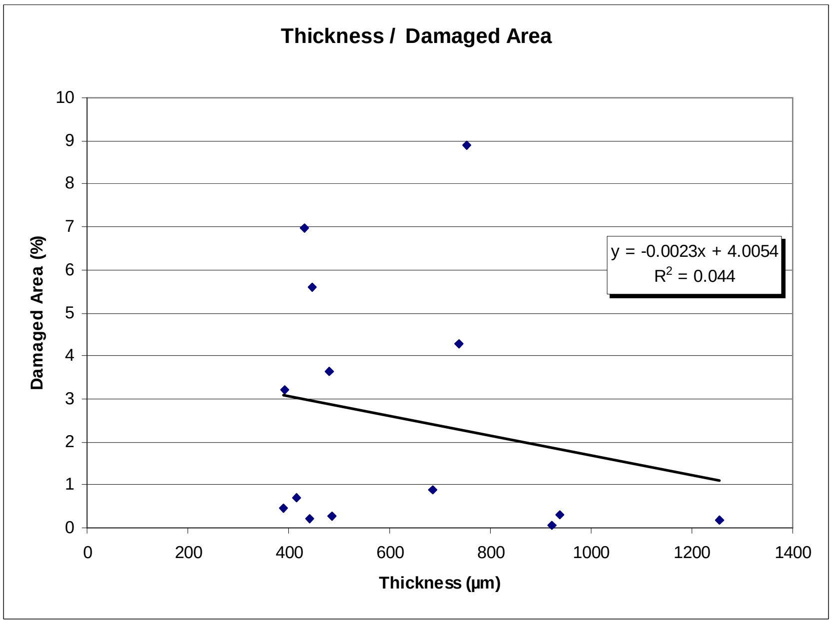

Fig. 4: Correlation with Thickness

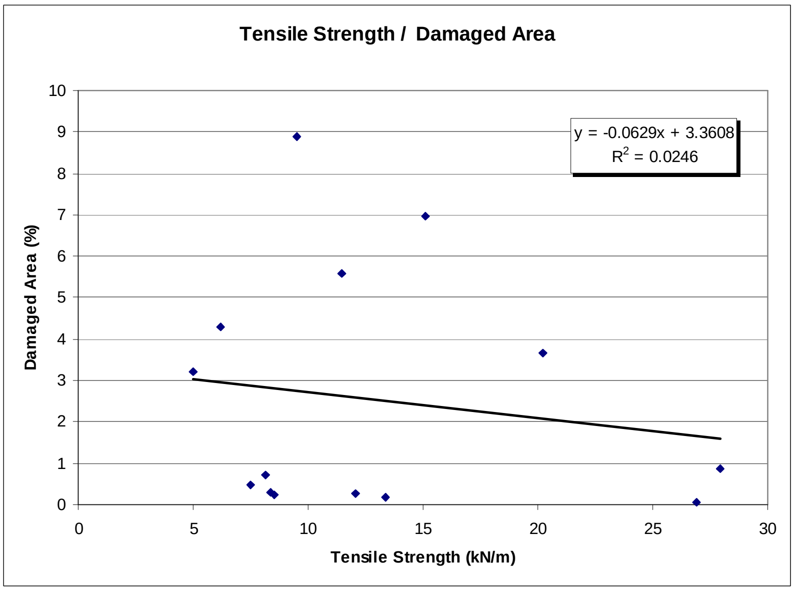

Fig. 5: Correlation with Tensile Strength

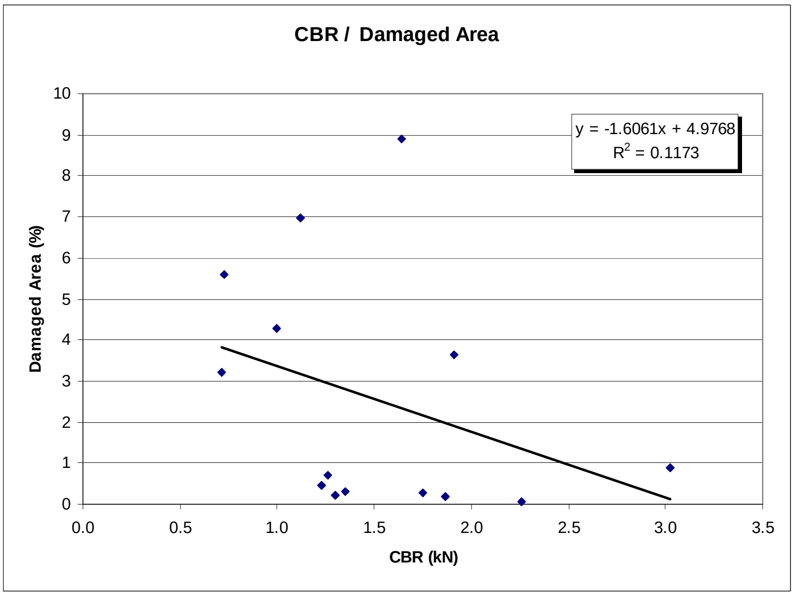

Fig. 6: Correlation with Puncture Strength

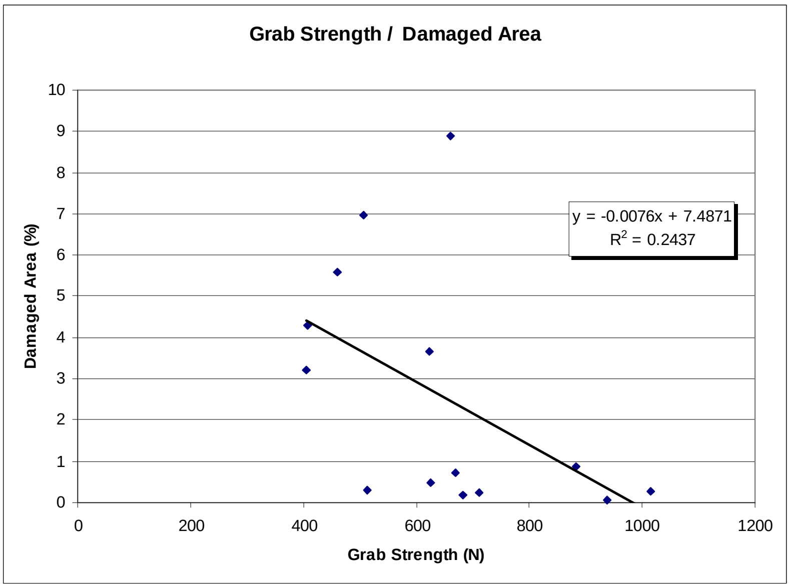

Fig. 7: Correlation with Grab Strength

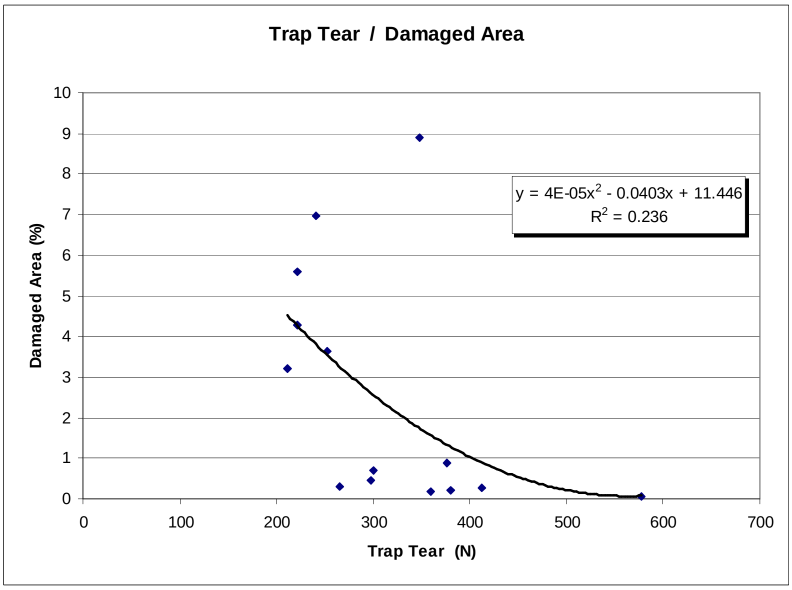

Fig. 8: Correlation with Tear Strength

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).

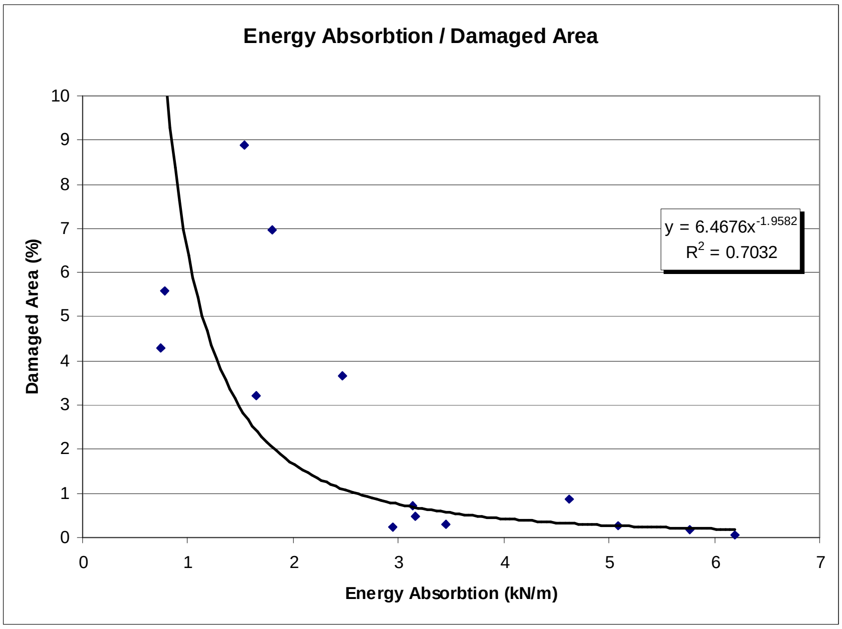

Fig. 9: Correlation with Energy absorption

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

2.5. Conclusion from the test

The project provided useful information for evaluating the relevant properties and requirements for geotextiles to avoid damage during installation.

The results have shown that most properties used in several specification and classification systems do not reflect the behavior in the field and support the approach 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 of the performance related criteria.

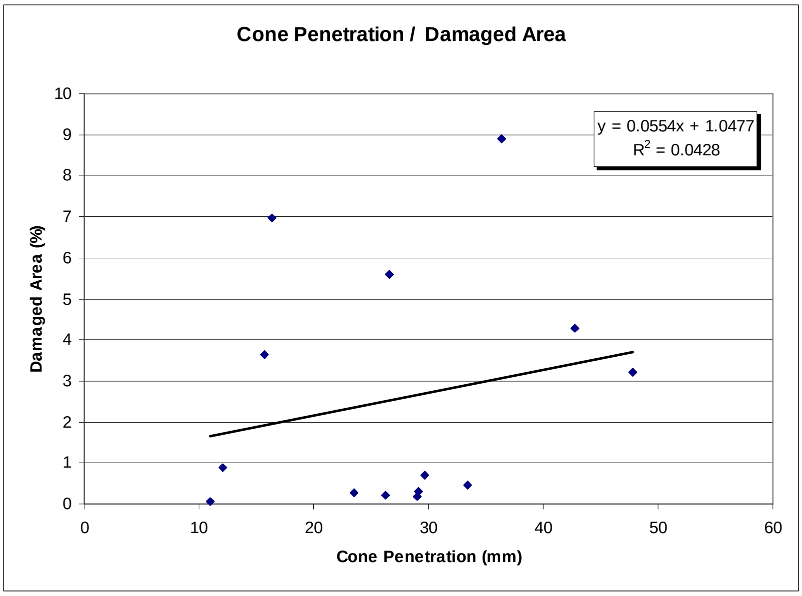

Fig. 10: Correlation with Cone Penetration

3. INTEGRATION OF THE ENERGY ABSORPTION IN THE 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 non-woven geotextiles. The AASHTO M288-96 classification requires higher mechanical properties for geotextiles of lower elongation and sets the limit empirically at the elongation level of 50%.

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 the given elongation of 50% (with an exception of class A), but allows compensating lower elongation by higher strength (Fig. 11). As a result, products with the same energy absorption or the same damage resistance are specified rather than products with e.g. similar tensile strength but different behavior under stress.

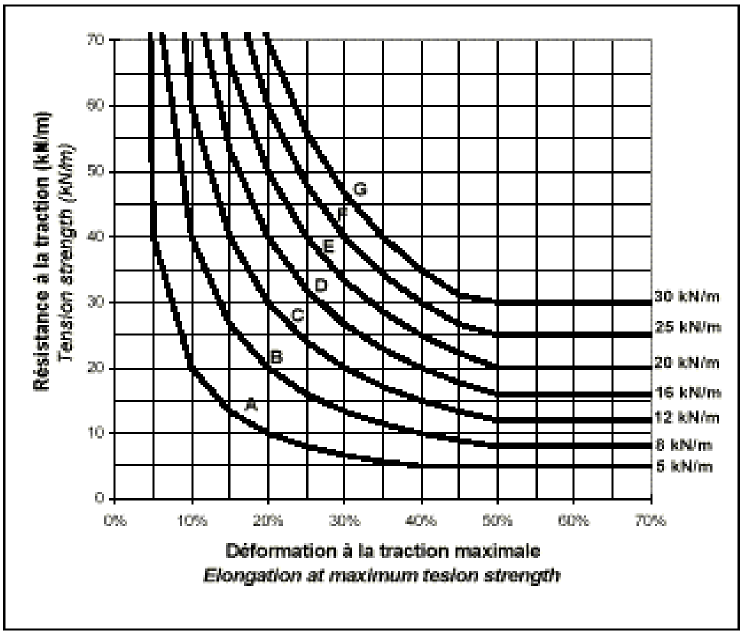

Fig. 11: French energy absorption concept proposal: J.C. Blivet, Rencontres Bordeaux 1999

3.2. Norway and Switzerland

The new Norwegian standard NS 3420-13 (1999) and the Swiss standard SN 640 552 (1997) both define the energy absorption capacity of a geotextile as half of the product of the tensile strength multiplied by the elongation at the maximum load, which is a simplified approach.

Norway, Finland and Sweden together have adapted the NorGeoSpec2002. This new specification system is based on the required characteristics and test methods standardized by CEN, but also incorporates the energy absorption potential as one of the dominant criteria.

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 theoretical approach and define energy absorption as the product of tensile strength (T) and elongation (ε_f) at the maximum strength

$$E = ½ * T * \varepsilon_f . \qquad (1)$$

In order to differentiate between the actual and simplified energy absorption potential a proposal was made for the European norm 10318 to define the energy absorption W (area under the stress-strain curve for tensile strength) and an energy absorption index W_i as described above.

In a further effort on a European level, the proposal has been made to add the measurement of the energy absorption potential in the European norm 10319.

The new European application standard EN 13249: « Required characteristics for geotextiles and geotextile-related products used in the construction of roads and other trafficked areas », requires the following characteristics for the separation function: Tensile strength, elongation at the maximum load, static puncturing (CBR), dynamic perforation as well as hydraulic properties.

4. CONCLUSIONS

The 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 recognized as a significant property in the geotextile selection process .

The final version of the new French classification is strongly anticipated as well as the revision of EN 10318 and EN 10319.

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