Evaluation of Installation Damage of Geotextiles. A Correlation to Index Tests

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ABSTRACT

A research program was performed in order to study the behaviour of woven and nonwoven geotextiles under field conditions. A new test method was developed to allow a rapid evaluation under different controlled and repeatable conditions.
The project objective focused on the correlation between properties determined by the standard index tests and the actual measured damage. The research showed that most national geotextile specification and classification systems are not representative of the performance behaviour of geotextiles under real field conditions. Common criteria for all geotextiles is proposed based on the combination of deformation energy and stress-strain properties.

1. INTRODUCTION

Geotextiles are used since many years in various applications such as separation, filtration, reinforcement and protection. To perform any of these functions, it is essential that the geotextile remains intact and is not destroyed during or immediately after installation. Analyses and field tests indicate that the critical period in the life of a geotextile is during the installation and construction phases rather than during the service life. Typically, if the geotextile survives the construction-induced stresses, it will also withstand the in-service stresses.

To ensure installation damage resistance, minimum mechanical properties are usually specified so that a product meeting the application requirements can be selected.

1.1 Specifications, classifications and equivalence

In earlier times when geotextiles were in their infancy, geotextiles were frequently specified by either weight per unit area or by "brand name xxx or equivalent". Many countries subsequently developed a more scientific approach and introduced different national specification and classification systems.

One of the first such systems was introduced by the Norwegian Road Research Laboratory (Alfheim and Sørlie, 1977). The French recommendations from the CFG[1] in 1981 took the approach of specifying several properties depending on the structural characteristics (supporting ground, traffic, nature and thickness of the fill material). In Germany a high number of experimental field and laboratory tests were conducted (Technical University Munich and Forschungsgesellschaft für Straßen- und Verkehrswesen) which served as the basis for the German classification system (Merkblatt für die Anwendung von Geotextilien und Geogittern im Erdbau des Straßenbaus). A similar approach was also adopted in the USA and a classification system was introduced in 1990 by AASHTO[2]

[1] Comité Français Géosynthéthiques
[2] American Association of State Highway and Transportation Officials

1.2 Properties and test methods utilised by current classification systems

Despite the similarity of geological structures, available materials and construction techniques, the various national specification systems differ quite significantly.

Properties such as tensile strength, puncture resistance and unit weight have long been recognised as the key parameters. Some systems consider also the importance of both strength and elongation properties. For example, the German classification system differentiates between woven (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 level.

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. Furthermore, a recently developed European laboratory standard test method aiming to simulate quantitative damage during geotextile installation is currently being evaluated. (M. Khay: 1998 French Experience of Mechanical Damage)

1.3 The energy absorption concept

Certain national European classification systems are now beginning to incorporate the "elongation factor" into the combination of key properties and express the performance requirements in terms of the energy absorbing capabilities of the geotextile.

Energy absorption is defined by the area under the stress - strain curve
The energy absorption (kN/m) is the maximum energy a Geotextile can absorb before failure.

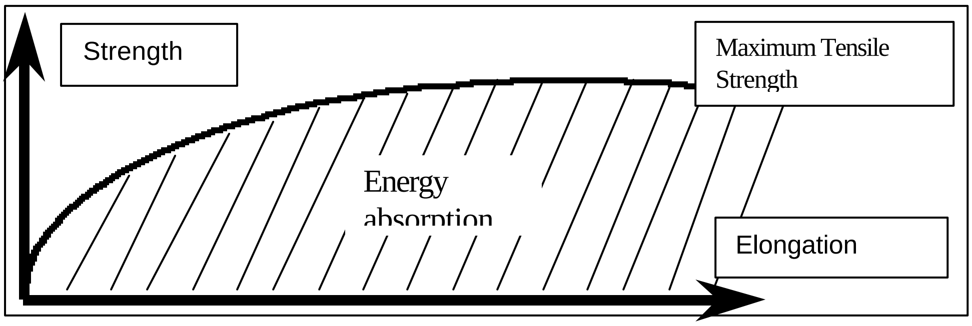


Figure 1: Energy absorption

SINTEF (Watn, Eiksund, 1997) performed field trials on different nonwoven geotextiles and concluded that the energy absorption of geotextiles is an important parameter in the determination of damage resistance. The new Norwegian standard NS 3420-13 (1999) and the Swiss standard SN 640 552 (1997) define the energy absorption capacity of a geotextile as the product of the tensile strength multiplied by the elongation at maximum load. A recent recommendation for a new French classification has been proposed by J.C. Blivet in 1999. The proposal also takes into account the energy concept as the main criteria for the specification of all geotextiles.

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 maximum strength.

$$e = \tfrac{1}{2}\, T .\, \varepsilon_f$$

The principle of the French recommendation is to use a minimum strength at a given elongation, but allows compensating lower elongation by higher strength thus resulting in the same energy absorption or same damage resistance.

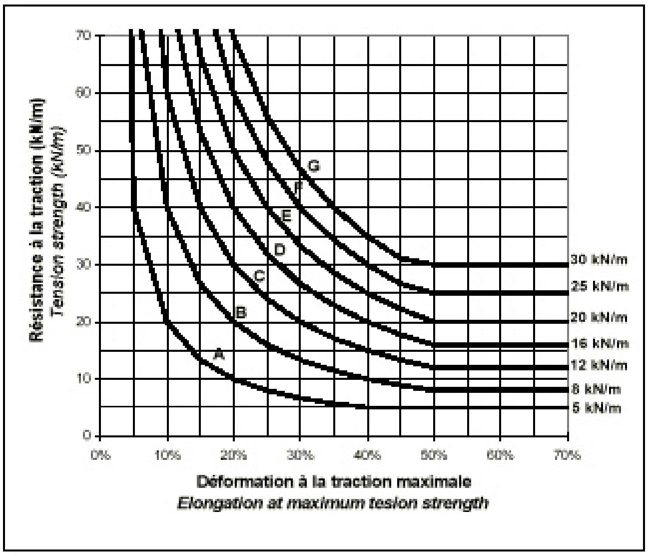


Figure 2: French energy absorption concept proposal: J.C. Blivet, Rencontres Bordeaux 1999

2 EVALUATION OF INSTALLATION DAMAGE

2.1 Product selection

A range of commonly used geotextiles for separation applications manufactured by different process technologies and of differing weights and mechanical properties was selected to perform the damage evaluation of the field test. Products selected were as follows

- 5 woven tape products
- 2 needle-punched continuous fibre nonwoven products
- 2 thermally bonded nonwoven (polypropylene/polyethylene based) products with low elongation properties (manufacturer A)
- 5 thermally bonded (100 % polypropylene based) nonwoven products with high elongation properties (manufacturer B)

Index tests most frequently used in specification and classification systems were performed on each of the geotextiles

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

Table 1: Products and Measured Properties

2.2 Test Method

In order to observe the behaviour of the geotextiles under field conditions, a new test methodology has been developed that allows a controlled installation and avoids any additional damage during the extraction of the geotextiles. The conditions were intentionally severe to ensure damage to all geotextiles, thus permitting a comparison and evaluation after extraction.

Steel plates (2 x 2.50 m) with steel chains at the edges were constructed. Compacted soft clay subgrade from the local site was placed ontop of the plates at a height of 25 cm. A 2 x 2 m geotextile sample was laid directly on the subgrade and covered with a 25 cm high layer of high furnace slag (40-60cm diameter) dropped from a height of 50 cm. The system was compacted with a 7-tonne vibratory roller with 4 passes (forward and backward).
Following compaction, the steel plate with soil/geotextile system ontop, was gently tilted and lifted, so that the aggregates slid along the geotextile without creating any additional puncturing or damaging.
All Geotextiles could be installed and extracted under identical conditions.

2.3 Evaluation of damage resistance

After cleaning, the edges (25cm) were removed, and the remaining surface area (1.50 x 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 x 1.5 m template with a pre-determined pattern was placed on each sample, used in order to cut 10 specimen in both machine and cross directions thus ensuring that the same position for each geotextile sample was used to evaluate the remaining tensile strength after extraction.

	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

Table 2: Evaluation of damaged area and retained strength

3 DISCUSSION OF RESULTS

The correlation of the total damaged surface area (%) with all of the index tests has been compared. A good correlation has been observed between the damaged surface area and retained strength.

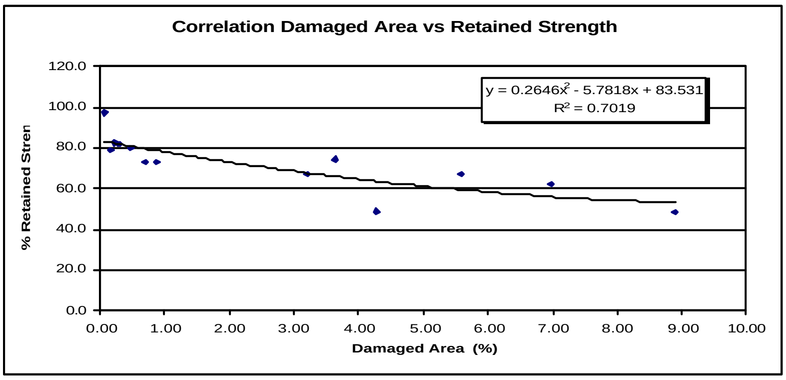


Figure 3: Correlation between damaged area and retained strength

Unit weight and thickness are descriptive properties only and do not provide any information relating performance when comparing different products. Only for products of the same "family" (i.e. manufactured according to the same process), is the damage resistance 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. 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.

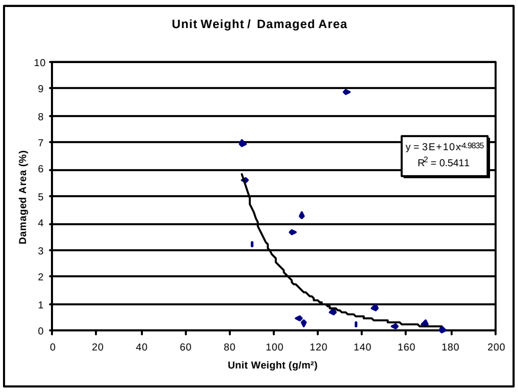


fig :4 Correlation with Area Weight

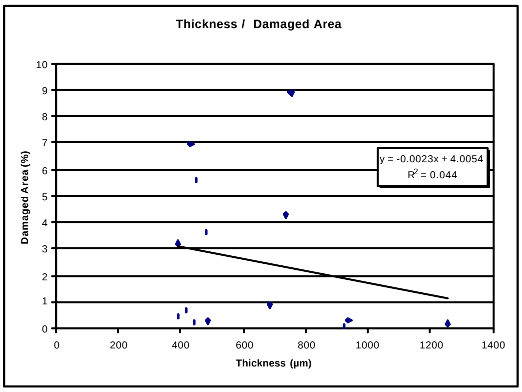


fig :5 Correlation with Thickness

No correlations were identified between the damage and any of the mechanical properties such as tensile strength, CBR puncture resistance, grab tensile strength and tear resistance.

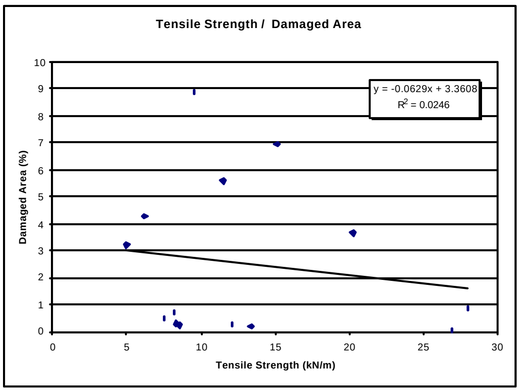


fig :6 Correlation with Tensile Strength

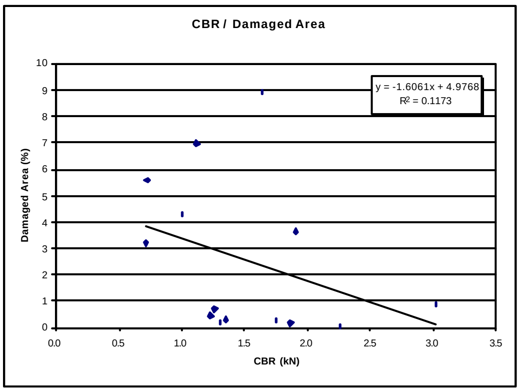
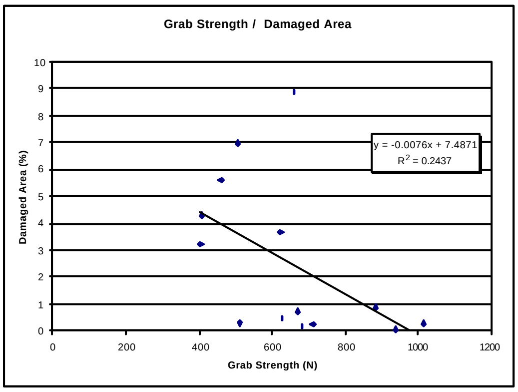


fig :7 Correlation with Puncture Strength



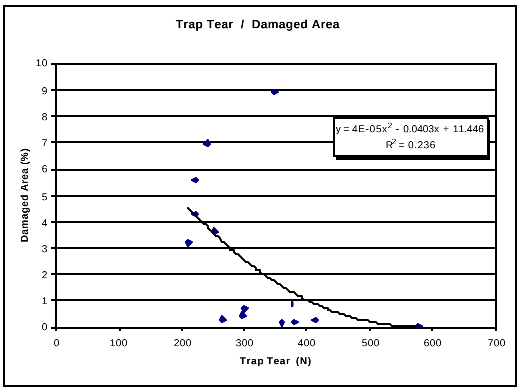
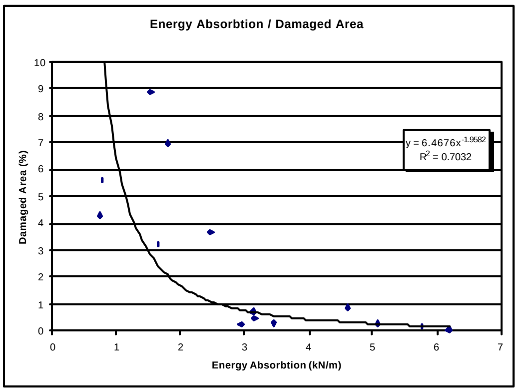


fig :8 Correlation with Grab Strength

fig :9 Correlation with Tear Strength

Although dynamic puncturing (Cone Penetration) is usually seen as a performance test simulating real conditions, little correlation has been observed during this test.
As the dropping height in the trial was however limited to 50 cm, the cone penetration test may have a higher significance as the aggregate dropping height increases.

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



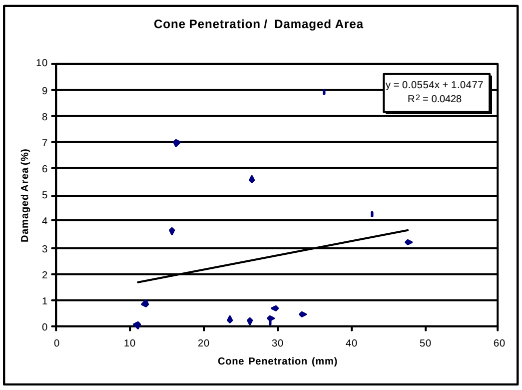


fig : 10 Correlation with Energy absorption

fig : 11 Correlation with Cone Penetration

4 CONCLUSIONS

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 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.

5 REFERENCES

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6 Attachment

Installation

Compaction (4 passes)

Extraction