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Dutch progress in the standardization of geotextile test methods

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ABSTRACT: Dutch progress is reported in the standardization of test methods for the determination of geotextile properties. Draft standards of permittivity and characteristic pore size tests are outlined.
Results are presented of an interlaboratory test programme on tensile strength test methods. The influence of specimen width and clamp system is discussed.

1 INTRODUCTION

The concept of functional design becomes more and more accepted in the geotextiles engineering world.
The general idea of functional design is well described by Koerner (1986) and takes as a starting point the functions that a geotextile has to fulfil in a specific application.
It goes without saying that standard methods for testing all possible properties of geotextiles which relate to those functions are vital for both industry, designers and last but not least, for the structure of which the geotextile becomes a part.

This paper deals with results that were obtained so far by the hydraulic and mechanical working groups of the Dutch Standardization Committee on Geotextiles (353 50). As yet both working groups confined themselves to so-called index tests. Performance tests will be dealt with later on.

The hydraulic group has drafted a standard on the determination of the permittivity and of the characteristic pore size of geotextiles, see 2.

Up to now the Working Group on Mechanical Properties has focused mainly on tensile properties.

Where it is believed appropriate the Dutch Standardization Committee seeks agreement with international developments.

2 HYDRAULIC PROPERTIES

2.1 Introduction

Hydraulic aspects are involved in the filter function, the separation function and the drainage function of geotextiles. Very often these functions are of primary interest, e.g. in erosion control.

In terms of functional design, the main properties of geotextiles to fulfil these functions are:

- permittivity, related to water permeability through the geotextile
- transmissivity, related to water permeability in the geotextile plane
- characteristic pore size, related to its capacity of soil retention.

2.2 Permittivity

The permittivity of a geotextile is defined as the ratio between the filter velocity and the hydraulic head over the geotextile specimen.

$$\psi = \frac{u_f}{\Delta h} \qquad (1)$$

where

ψ is the permittivity in s^{-1}
u_f is the filter velocity through the geotextile in m/s
Δh is the head in m

Groundwater flow generally is expressed in terms of permeability coefficients (m/s).

Taking a geotextile as a porous medium,

through the concept of the permittivity ψ one can arrive at a geotextile permeability coefficient k by assuming Darcy's law.

$$u_f = k \cdot \frac{\Delta h}{t_g} \qquad (2)$$

where t_g is the geotextile thickness in m

Comparison of (1) and (2) gives

$$\psi = \frac{k}{t_g}$$

Yet, this formula is too much simplified, since it does not take into account the nature of the flow regime.

With sufficiently low filter velocities flow through the geotextile will be laminar and there is a linear relation between filter velocity and hydraulic head, i.e. ψ is a constant.

With higher filter velocities, however, flow through the geotextile is no longer laminar, it becomes turbulent and the permittivity ψ becomes a function of the filter velocity. Therefore a standard filter velocity must be used.

A second reason why permittivity and permeability are not readily correlated concerns Darcy's law, which is valid for laminar flow conditions.

Following Forchheimer (1901) the non-Darcy relation between filter velocity and hydraulic head reads:

$$\frac{\Delta h}{t_g} = a \frac{u_f}{k_g} + b\left(\frac{u_f}{k_g}\right)^2 \qquad (3)$$

where a and b are dimensionless constants and k_g is a geotextile constant with dimension m/s.

Darcy's law follows from (3) with b = 0.

Pure turbulent flow results if a = 0.

The permittivity ψ can now be obtained by rewriting (3). It follows

$$\frac{1}{\psi} = t_g\left(\frac{a}{k_g} + \frac{b\,u_f}{k_g^2}\right) \qquad (4)$$

again describing ψ as a function of the filter velocity.

Although the existing Dutch draft standard has not been based on the Forchheimer approach, it is believed that an ideal test method would determine the constants a and b and thus establish relation (4), which is valid for both laminar and turbulent flow conditions.

The flow type dependency of the permittivity has lead to the use of a standard filter velocity u_s of 10 mm/s. The alternative of a standard hydraulic head has been discarded since the criterion for the flow regime, the Reynolds number, depends on the filter velocity, not on the hydraulic head.

2.3 Permittivity test procedure

The Dutch draft standard method for the determination of the permittivity precisely describes the principles, terminology, test equipment, test execution including sampling and specimen preparation, calculations and logging of relevant data.

As an example Table 1 shows results of five measurements on one specimen.

From Table 1 it can be derived, that at the standard velocity u_s = 10 mm/s the head equals 36 mm.

The average temperature was 13 °C, giving a temperature corrected standard hydraulic head of 39 mm.

The standard permittivity ψ_s becomes

$$\psi_s = \frac{u_s}{\Delta h_s} = \frac{10}{39} = 0.26\ s^{-1}$$

Table 1. Measurements on one specimen for permittivity calculation

test no.	head Δh (mm)	mass of passed water m_i (g)	time interval t_i (s)	water temp. (°C)	filter velocity $u_i = \frac{1000\ m_i}{A\ t_i}$ (mm/s)
1	10.5	161	20.0	13.4	4.1
2	4.5	113	24.0	13.2	2.4
3	27	215	15.0	13.1	7.3
4	63	316	10.0	13.0	16.1
5	149	529	10.0	12.8	26.9

A is the effective flow area = 1963 mm²

Table 2. Sieve test results for the characteristic pore size determination

specimen	sand fractions (μm)	D_m (μm)	amount of passed sand (g)	amount of sand on and in the geotextile (g)	percentage of sand on and in the geotextile (%)
1	250 - 300	275	8.01	41.99	83.98
	300 - 355	328	4.03	45.97	91.94
2	250 - 300	275	9.11	40.89	81.78
	300 - 355	328	3.96	46.04	92.08
3	250 - 300	275	7.84	42.16	84.32
	300 - 355	328	3.38	46.62	93.24
4	250 - 300	275	10.23	39.77	79.54
	300 - 355	328	5.53	44.47	88.94
	355 - 425	390	2.77	47.23	94.46
5	250 - 300	275	7.01	42.99	85.98
	300 - 355	328	2.63	47.37	94.74

2.4 Characteristic pore size test procedure

The draft Dutch standard method for the determination of the characteristic pore size is based on the Delft Hydraulics method of dry sieving with well specified sand fractions according to NEN 2560 (Veldhuijzen van Zanten, 1986: 176-213).

The pore size O(p) is defined as the pore size in the geotextile that equals the average grain size of a hypothetical sand fraction, of which p% remains on and in the geotextile after execution of the standard test.
The execution of the standard test is precisely described and includes principles, terminology, test equipment, sampling and specimen preparation calculations and logging of data.
Subsequent sievings with 50 g of selected sand fractions is prescribed during 300 ± 2 s with a vertical amplitude of 0.75 mm and a frequency of 50 Hz.
As an example of the determination of the characteristic pore size consider table 2, where the relevant test quantities are listed. D_m is the average grain size of the selected sand fractions.
Mean value and standard deviation per sieved sand fraction of sand percentage that remain in and on the geotextile can now easily be determined. Finally the O(90) can graphically be derived giving O(90) = 314 μm.

3 MECHANICAL PROPERTIES

The purpose would be to standardize only one test method that applies for both woven and non-woven fabrics (ISO TC38/SC21). With this in mind the Strip Tensile Test and Wide-Width-Tensile-Test methods are discussed below.

3.1 Strip Tensile Test (S.T.T.)

The S.T.T. (e.g. ISO 5081, width/length = 50/200) has been used for many years to assess the load-elongation characteristics of textile fabrics.
For geotextiles (ranging from high-elongation non-wovens with a strength of 5 kN/m to coarse, sometimes high-modulus, woven fabrics with a strength of 1000 kN/m) the S.T.T. however has some deficiencies.
For geotextiles with a high lateral contraction (most non-wovens, some types of woven fabrics) the S.T.T. does not give a fair indication about the real strength of the geotextile used in full width (generally of the order of 5 m). The S.T.T. can yield either much too low values, or (even) too high values. Which one will be the case depends on the geotextile structure, and is related to the degree of freedom of the constituent fibres or threads to reorientate during the tensile process. It also depends on the clamping system (fixed or frictional). In principle the S.T.T. is suitable only for (light) woven fabrics with little crimp, i.e. almost without any lateral contraction.

3.2 Wide-Width-Tensile-Test (W.W.T.T.)

To overcome some of the drawbacks of the S.T.T. for geotextiles, the W.W.T.T. has been developed (e.g. AFNOR 38014, W/L = 500/100).
Here, at least in the central part of the specimen, the lateral contraction is nearly zero, so more or less the desired plane strain state is reached (i.e. deformations are limited to planes in tensile direction and perpendicular to the specimen).

At the edgings of the specimen, however, lateral contraction still develops, leading to stress concentrations and initiation of failure.
This can be observed especially at the corners of the specimen, where the discontinuity from the fixed, compressed state in the clamp to the free state outside the clamp has its influence.

Nevertheless, the use of stiff, fixed clamping systems is essential for the W.W.T.T., otherwise the state of plane strain will not be obtained anywhere. For capstan clamps the effective gauge length is increased so far that a high W/L ratio cannot be accomodated on existing tensile machines.

For strong woven fabrics the W.W.T.T. has comparable drawbacks, as with large specimen widths the load capacity of nearly all testing machines will appear to be insufficient. Furthermore, problems related to satisfactory clamp constructions will increase excessively.

To investigate acceptable compromises between the S.T.T. and the W.W.T.T. the Dutch Interlaboratory Test Programme has been set up (see 3.4).

3.3 Test procedure of load-elongation measurement

The edges of a specimen can be prepared in different ways. It is preferred to prepare the width of the woven specimen by ravelling and that of the non-wovens by cutting.
The very measurement of the force is technically not a problem.

A correct measurement of the extension is more difficult, however. In practice the displacement of the (stiff) clamps is often used as a measure for the extension of the specimen. Because of the slipping of the specimen this measurement is not correct.
At the same time the extension of the material, especially in inhomogeneous non-wovens, varies a lot from place to place.

For calibration reasons a pre-tension of the specimen shall be prescribed, e.g. 1 % of the nominal tensile strength.
The origin of the strain axis coincides with the pre-tensioned state. The so-called daylight point (BS 6906: Part 1) cannot be measured in a reproducible way and is unusable.
In the case of capstan clamps the use of an extensometer is a must.

Mostly the rate of extension is realized by a constant rate of the moving clamp, but should be expressed for comparison reasons in rate of strain (e.g. in %/min). Because various materials have different strains at break, it is important to prescribe an average time-to-break. The textile standard is either 20 or 30 s, but in view of the highly extensible non-wovens the according rate of extension can be too high. A time-to-break between 1 and 2 minutes is therefore suggested.

3.4 The Dutch Interlaboratory Test Programme

In the Netherlands an interlaboratory test programme was set up, in which 6 laboratories participated.
For this test 10 types of current geotextiles have been selected, together covering a wide range of production techniques and stress-strain behaviour (see figure 1 and table 3).

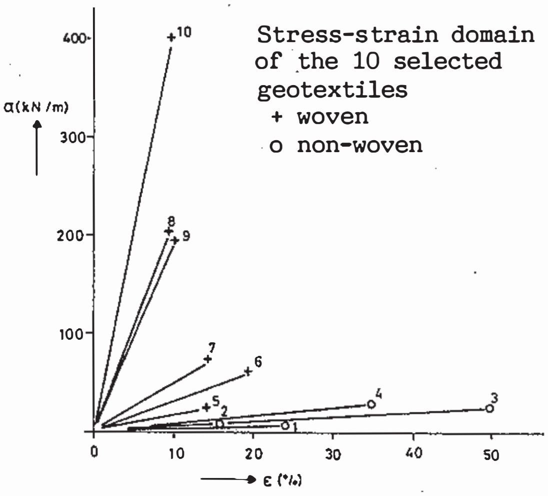

Fig. 1

All important geotextile structures and materials are represented in this scheme. Most difficulties were to be expected both with geotextiles exhibiting high elongation/high lateral contraction and with high-strength, high-modulus woven fabrics.

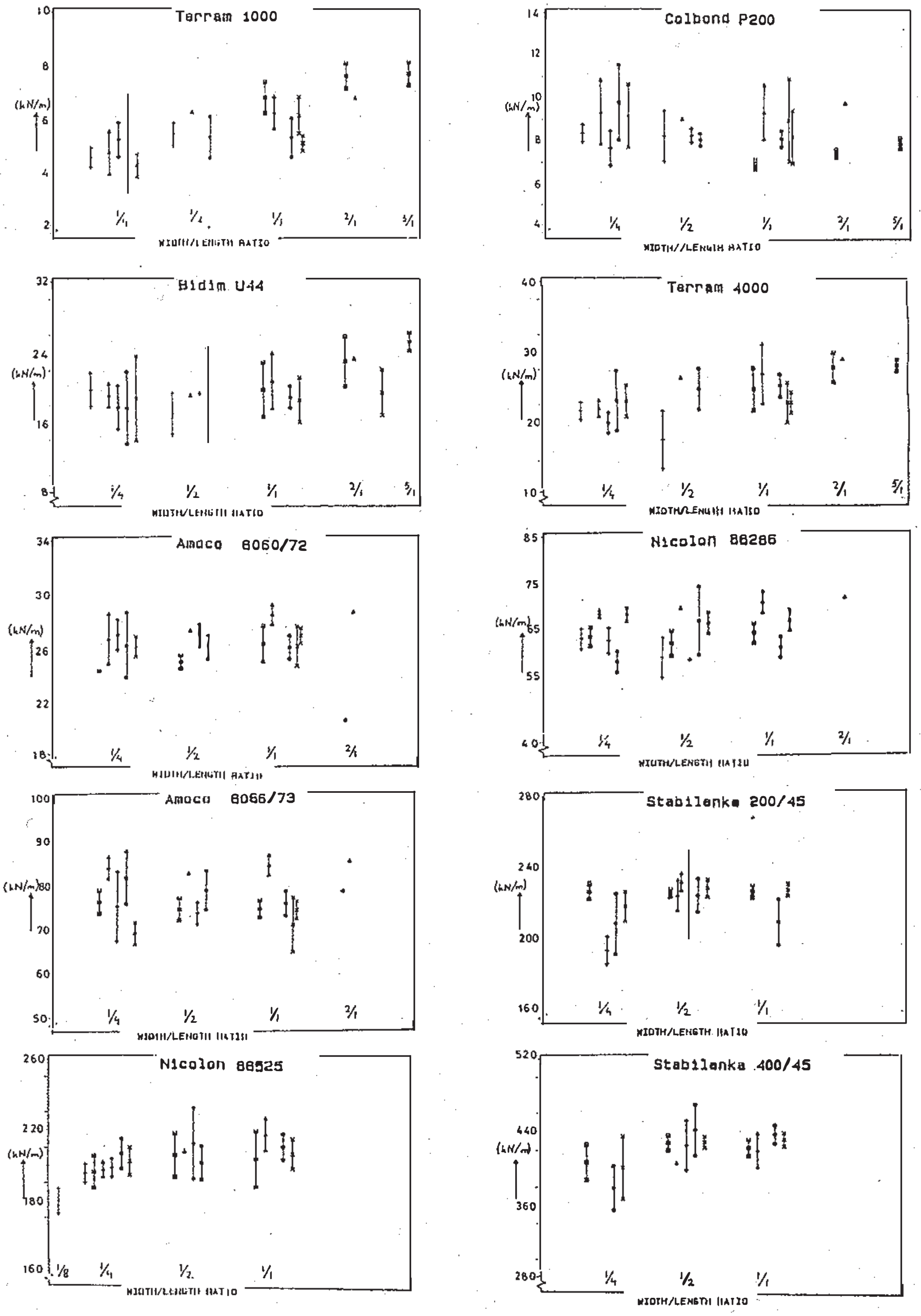

Fig. 2 Maximum force (kN/m) of 10 geotextiles, determined in tensile tests by 6 laboratories at different width/length ratio's.

Table 3: Description of the 10 geotextiles

					nominal values		
	Type	structure	polymer	brand	weight (g/m²)	α (kN/m)	ε_f (%)
1	NW	fil., TB	PP/PE	Terram 1000	140	8	24
2	NW	sf, NP, CB	PETP	Colbond P200	200	8	16
3	NW	fil., NP	PETP	Bidim U44	340	24	50
4	NW	tapes	PP/PE	Terram 4000	370	28	35
5	W	fil., TB	PP	Amoco 6060	140	24	14
6	W	multifil.	PA	Nicolon 66286	215	65	20
7	W	splitfibre	PP	Amoco 6066	520	74	15
8	W	multifil.	PETP	Stabilenka 200	450	200	10
9	W	splitfibre	PP	Nicolon 66525	780	200	10
10	W	multifil.	PETP	Stabilenka 400	820	400	10

Used abbreviations and symbols:

α	tensile strength per unit width (kN/m)	NP	needle punched
		CB	chemical bonding
ε_f	elongation at max. force	TB	thermobonding
NW	non-woven	PA	polyamide
W	woven	PE	polyethylene
fil.	filament	PETP	polyester
sf	staple fibre	PP	polypropylene

The six participating laboratories were:
- Akzo Industrial Systems, Arnhem
- Amoco Fabrics, Gronau
- Nicolon, Almelo
- TNO-Fibre Institute, Delft
- Techn. University Delft, Dept. of Civil Engineering
- Techn. University Delft, Dept. of Mech. Engineering

The laboratories agreed upon the following regulations for the interlaboratory test:
- registration of test conditions (normally T = 20 °C, RH = 65 %)
- tests only in length direction
- time-to-failure between 1 and 2 minutes
- number of specimens per sample per test width: 5
- test width (if possible): 50, 100, 200 and 500 mm

The results concerning the tensile strength are presented in Fig. 2, where vertical lines represent 95 % confidence intervals.
Results concerning elongations, lateral contraction and modulus are still in statistical evaluation, and cannot yet be presented.

4 PRELIMINARY CONCLUSIONS

1. In general the geotextile permittivity is a function of the flow regime and thus of the filter velocity. Therefore a standard filter velocity for an index test must be used.
2. The concept of permittivity may become a reliable design tool when properly related to both laminar and turbulent flow conditions. Forchheimers approach is suggested.
3. The Wide-Width-Tensile-Test offers a possible solution to some problems related to lateral contraction of non-wovens; for strong woven fabrics, however, a large specimen width increases the testing difficulties significantly.
4. For non-woven fabrics the use of stiff clamps can be recommended. For woven fabrics the use of capstan clamps is often favourable.
5. For woven fabrics a specimen width of 100 mm could be recommended. The width/length ratio can be chosen between 1/2 and 1/1.
6. For non-woven fabrics a specimen width of 200 mm could be recommended, in combination with a length of 100 mm, (W/L = 2).

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