C.R. Coll. Int. Sols Textiles. Paris 1977

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Testing and classification of fabrics for application in road constructions
Méthodes d'essai et classification des textiles en construction routière

RÉSUMÉ

Le Laboratoire de Recherche Routier en Norvege a mis en usage quelgues méthodes d'essai tres simple pour évaluer les caractéristiques des textiles différentes. On a fait les essais de traction multidirectionelles dans une machine CBR ordinaire aussi bien que les essais de pénétration tres simple qui experiment la resistance à pénétration des textiles par des objets aigues. - Ces methodes d'essai ne sont pas les ideals, mais les résultats peuvent servir de séparer des textiles différentes. Avec point de départ dans ces caractéristiques mécaniques on a fait une classification des textiles à l'égard des domaines d'emploi.

INTRODUCTION

Fabrics have been used in the construction of both temporary and permanent roads as well as forrestry roads and alike, in Norway since 1972. The increase in use has been remarkebly rapid and is most probably due to the improvement in site conditions when used on soft and troublesome soils. Compared with other new synthetic materials for road construction, like insulating materials for frost protection, the road builders have adopted the fabrics very easily.

The economical aspect is of course the most important one for people involved in road construction.
The users have learned that the most important effect of the fabric is what can be termed as the membrane effect or separation effect. For instance can a permeable material like a fabric function like a filter layer just like a conventional sand filter, but at a comparatively lower cost.

In light of the rapidly growing expences in material and transportation costs and an environmental opinion wanting to take care of or use most natural sand and gravel resources for other purposes than road building, the fabrics seem to be a material with a big potential in road building.

Through testing and practical experience it has become clear that although a fabric is a relatively well-defined material, the properties will vary for each make and type, and so does the price. To be able to choose the most economical type of fabric for a job, there was the need for adequate and easily measurable parameters to describe the fabric. The first test methods to be used for this purpose were related to textiles and hence were of little interest to the civil engineer. Also, there was some doubt as to which parameters were of significant importance.

DEFINITIONS

The Norwegian Road Research Laboratory (NRRL) took at an early stage the consequence of this problem and started to look for suitable test methods for parameters thought to be of importance to the users. As a first step, a fabric can be defined as follows:

> A fabric is a synthetic material produced like a cloth with a structure of plastic fibres or filaments. The fibres being either directionally

oriented (woven) or randomly oriented (non-woven). The fibres are held together by physical, mechanical, thermic or chemical bonding, or a combination of these methods.

The non-woven fabrics are so far the only ones to be used to any considerable extent in Norway and the application of the test-methods therefore were primarely aimed towards these types.

The next step was to define the function of the fabric, and the following seem to be prevailing for most fields of application:

- separation
- filtering
- drainage

Considering the importance of the tensile strength using fabrics in road construcion for separation purposes and the inadequcy of the existing textile testing methods, the first aim was to come up with a simple, economical and standardized way of testing this parameter.

THE TENSILE STRENGTH TEST

To achive a test that to some extent could simulate the stress/strain - conditions in the field and that would give relative comparable results for different fabrics, a two-dimensional way of testing should be suitable. - It was found that a CBR testing machine could be used for this purpose (CBR= California Bearing Ratio). The CBR-machine is used testing the bearing capacity of soils by pressing a 2 inches piston into a soil specimen compacted in a 6 inches diameter cylinder. The piston being pressed into the soil specimen at a constant speed of 1,3 mm/min. The soil force on the piston is read by means of a measuring ring.

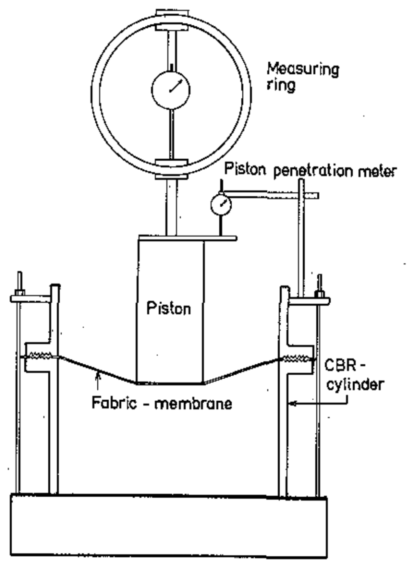

Fig. 1. Principle of CBR-machine used in testing fabrics.

For this test the fabric is mounted in the CBR-cylinder by pressing it between two cylinder-rings as a membrane. The fabric is stressed by the piston as in the ordinary CBR-test. As the piston is pressing the fabric downwards, the force is read by the measuring ring, see fig. 1. The stronger the fabric, the larger the force on the piston at a certain piston movement.

The force on the piston, Fp, to be measured, is in balance with the vertical component of the force in the fabric membrane, F_F. The fabric is then making an angle "a" with the horizontal plane, see fig. 2. This angle can be calculated from the piston movement and the distance between the cylinder and the piston, see fig. 2. It follows that:

$$Fp = F_F \cdot \sin a$$

$$F_F = \frac{1}{\sin a} \cdot Fp \qquad \text{---------} \; (I)$$

The stress in the fabric can be calculated as a function of the piston movement and the force on the piston.

It is assumed that the stress is uniformly distributed on the circumference. That means that the fabric is assumed to have the same strength in both the length and width directions. At a distance R from the piston (or cylinder) centre there is a force per unit length (tensile stress) in the radial direction, T:

$$T = F_F \cdot \frac{1}{2\pi R}$$

This simple equation can be rewritten by using equation I:

$$T = \frac{1}{2\pi \cdot \sin a} \cdot \frac{Fp}{R} \qquad \text{-----} \; (II)$$

The tensile stress is largest where the radius is smallest, this means at the edge of the piston. A possible failure will occure just there and therefore this is the critical point to be considered.

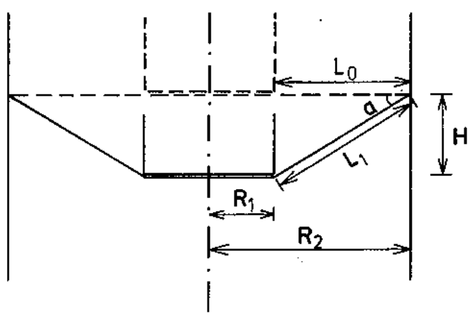

Fig. 2. Principle of the piston movement and elongation of the fabric.

It is desirable to express the tensile stress as a function of the relative elongation of the fabric, but the latter is not easily calculated. The average relative elongation of the fabric between the piston and the CBR-cylinder can, however, be calculated from the piston movement (H), the distance between the piston and the CBR-cylinder (Lo), and the length of the fabric between the piston and the cylinder (L1), see fig. 2:

$$\varepsilon_{av.rel.} = \frac{L_1 - Lo}{Lo} = \frac{\sqrt{Lo^2+H^2} - Lo}{Lo}$$

$$\varepsilon_{av.rel.} = \sqrt{1 + \frac{H}{Lo}^2} - 1 \quad \text{------(III)}$$

As the tensile stress is decreasing with the distance from the piston, the relative elongation will be decreasing too. It is the relative elongation at the edge of the piston, ε_1, which is interesting and the value of ε_1 will be larger than the average relative elongation. Calculation of ε_1 will be very complicated unless the modulus of elasticity (E) is assumed to be constant. This assumption is taken even if it is known to be somewhat inaccurate. As mentioned above the main purpose for this test was to compare the different types of fabrics and this inaccuracy or error involved will be introduced to all test results.

The radius of the CBR-cylinder is measured to be three times larger than the radius of the piston, i.e.

$$R_2 = 3 \cdot R_1$$

It follows, using equation II, that:

$$T_1 = 3 \cdot T_2 \quad \text{-------(IV)}$$

Assuming then E = constant:

$$\varepsilon_1 = 3 \cdot \varepsilon_2$$

or

$$\varepsilon_2 = \frac{1}{3} \cdot \varepsilon_1 \quad \text{--------(V)}$$

The average relative elongation is expressed as:

$$\varepsilon_{av.rel.} = \frac{\varepsilon_1 + \varepsilon_2}{2}$$

Using equation V, we get:

$$\varepsilon_{av.rel.} = \frac{2}{3} \varepsilon_1$$

or:

$$\varepsilon_1 = \frac{3}{2} \varepsilon_{av.rel.} \quad \text{------(VI)}$$

The relative elongation at the edge of the piston can then be expressed by the equations III and VI:

$$\varepsilon_1 = \frac{3}{2} \left(\sqrt{1 + \left(\frac{H}{Lo}\right)^2} - 1\right) \quad \text{----(VII)}$$

This equation gives the relative elongation at the edge of the piston as a function of the piston movement (H), assuming E=constant.

It is now possible to draw the curves for the tested fabrics in a tension-elongation diagram using T from equation II and ε_1 from equation VII, see fig. 3. The curves will unveil whether the assumption, E = constant, will be acceptable. Close to elongation at failure the modulus of elasticity will be decreasing and ε_1 will be larger than expected;

$$\varepsilon = \frac{\sigma}{E}$$

The same conditions are governing when the tension-elongation curve shows a decreasing modulus of elasticity right from the starting point of the test.

It has been found that the fabric right underneath the piston will have an elongation during the test which is not taken into consideration. This means that the elongation calculated will be distributed on a length larger than expected. Therefore the real relative elongation is in fact less than the calculated one. This fact and the assumption that E = constant, will act in opposite directions and to some extent reduce the error of the final test results.

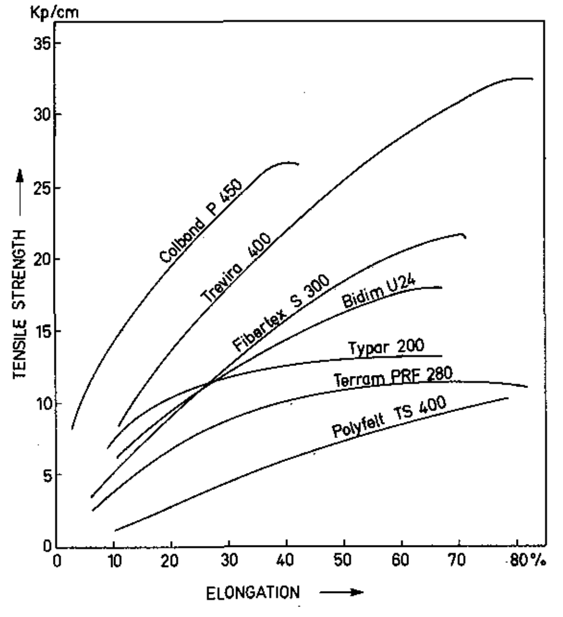

Fig. 3. A few results from testing fabrics in the CBR-machine.

This particular test method is being performed using testing equipment ment for other purposes and is therefore not ideal. There are sources of error that make the absolute test values somewhat uncertain. In addition to the above mentioned, there will be random effects influencing the stress in the fabric close to the piston. Furthermore it is assumed that the fabric is homogenious in both length and with directions. The speed of piston will also be of some importance. - Using the CBR-machine is a rather slow way of imposing stresses in a fabric.

THE CONE PENETRATION TEST

In Norway an important field of application for fabrics is the separation of sorted or unsorted blasted rock, used as subbase, from soft, often clayey subgrade. The construction technique consists of placing the fabric on the subgrade and dumping subbase material directly on it. Early experience showed that some types of fabrics had a greater tendency to become perforated than others. This kind of damage could not be related to the tensile strength, so the NRRL started to look for another simple test that could simulate sharp edged stones being dropped on the fabric.

The cone penetration test is simply performed by dropping a cone on a fabric fixed to a cylinder frame and suspended in free air, see fig. 4a. - The fabric is fixed in a CBR-cylinder in the same way as for the tensile strength test.

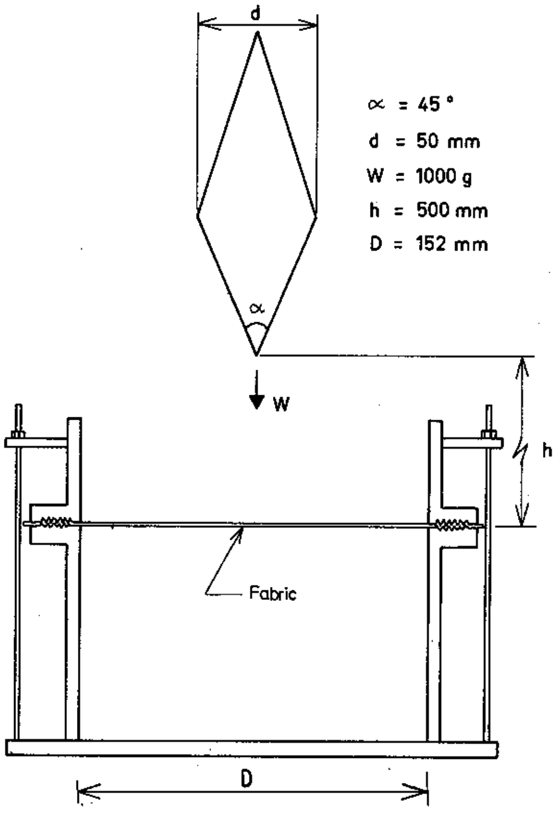

Fig. 4a: Cone penetration test apparatus.

The cone being dropped from a specified heigth, makes a hole in the fabric. The size of the hole is measured by means of a measuring device, see fig. 4b. This device is made like a cone with marks indicating the diameter of the cone from 0 to 50 mm in steps of 2,5 mm. The dropping heigth and the weigth and angle of cone has been choosen through experience. Normally ten drops are performed on each type of fabric. The aritmetic mean of the ten values is the one to be referred to for the type. In fig. 5 is shown the results from the cone penetration test on all the fabrics available in Norway.

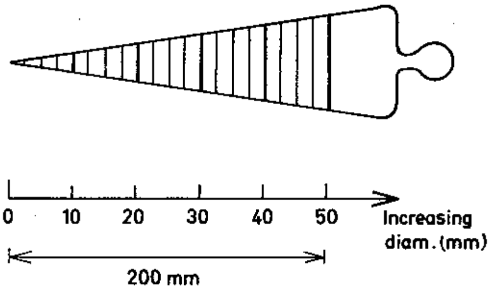

Fig. 4b. Cone penetration measuring device.

The results from such a test should not be taken as a measure of absolute performance but give relative values for the different types of fabric. Obviously, small figures indicate a good resistance against penetration. - Referring to figure 5, it appears that the needle-punch non-woven fabrics (Bidim, Polyfelt, Trevira) come out comparatively well. The most important factors influencing the test results are the type of fiber polymer, method of bonding and weigth of material per unit area.

CLASSIFICATION OF FABRICS

Whether one fabric is better than another depends mainly on the field of application. In road construction in Norway fabrics are used as membrane between soft soil and blasted rock as well as for erosion protection in cuts and on embankments. Obviously the two different field of application requires different types of fabric, not only technically but also economically as the price of the fabrics vary widely.

The most important properties of the fabrics are

- tensile strength
- resistance to penetration

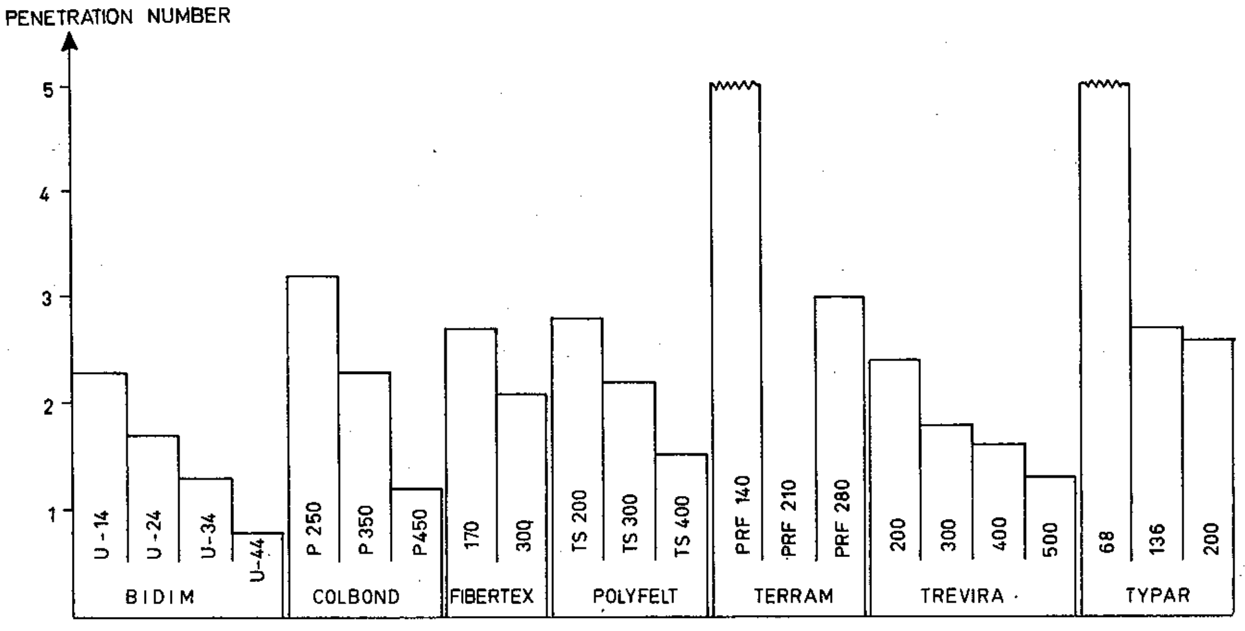

Fig. 5: Results from the cone penetration test.

- tear strength
- type of polymer
- filtration characteristics
- drainage characteristics

These are all properties that differ for each fabric and that can be determined by testing or otherwise. The most difficult properties to measure, are probably the filtration and drainage characteristics due to the complexity of testing. In Norway very little work has been done on these topics even though some practical experience is gained during the last few years.

Mainly based on the mechanical properties mentioned but also taken into consideration the filtration and drainage characteristics available, the NRRL has come up with a suggestion on a classification system for fabrics This classification system considers the intended field of application or function of the fabric, i.e. the environment under which the fabric will be placed. Hence the soil types or road construction materials adjacent to the fabric are the important ones, and the coarser one will be the critical.- The classification system has been established by giving the different fabrics points related to the quality for the different properties. The point system takes into consideration the number of properties measured and relate them to the field of application.

In fig. 6 is shown the classification set up of fabrics used in Norway, especially regarding road building.

COMMENTS

The two test methods described are of course not ideal, but are easy to perform and give relative values that makes the user able to compare the different fabrics. Being aware of the discreapensies of the tests, they seem to be valuable in classifying fabrics and both tests distinctly differs between good and poor quality. - The classification system proposed is definately not final and will be adjusted as more relevant informations on fabrics become available. Based on the present knowledge of fabrics, the system is ment to be helpful to users that otherwise would lack informations to base their choise on.

Name	Type	Producer	Polymer	Production method	Producers data g/m²	Producers data tensile strength at break kp/cm	NRRL test data Tensile strength at 20% def. kp/cm	NRRL test data Tensile strength max. kp/cm	NRRL test data Tensile strength def. at max str. %	Penetra-tion number 2)	Classifi-cation group 3)
COLBOND	P 250	Enka Glanzstoff AG (D,NL)	Polyester	Needle punching with resin bonding	250	14/8 1)	9,8	12,0	40	3,2	III
	P 450				450	27/16 1)	19,4	27,5	42	1,2	IV
FIBERTEX	S 170	A/S Fibertex (DK)	{95% Polypr. 5% Polyest.	Needle punching with melt bonding	170	6,4/8,0 1)	4,8	10,9	65	2,7	II
	S 300		{98% Polypr. 2% Polyest.		300	12/16 1)	9,2	21,8	70	2,1	III
POLYFELT	TS 200	Chemie Linz AG (A)	Poly-propylene	Needle punching	200	11	-	~7	77-80	2,8	II
	TS 300				250	13	2,1	-	-	2,2	II
	TS 400				350	16	2,6	-	-	1,6	III
TERRAM	PRF 70	ICI (GB)	75% Poly-propylene 25% Polyamid	Melt bonding	70	2,6	-	-	-	-	I
	PRF 140				140	4,9	3,2	5,5	70	> 5,0	II
	PRF 280				280	9,4	6,9	~10,6	~50	3,0	III
TREVIRA Spunbond	200	Hoechst AG (D)	Polyester	Needle punching	200	10	4,0	15,3	73	2,5	II
	300				300	15	7,7	23,2	78	1,9	III
	400				400	24	13,6	32,7	82	1,6	III-IV
	500				500	27	19,2	44,5	73	1,3	IV
BIDIM	U 14	Rhone-Poulenc-Textile (F)	Polyester	Needle punching	150	10	7,4	13,6	53	2,3	II
	U 24				210	16	9,3	~18	~65	1,7	III
	U 34				270	21	10,1	> 24	-	1,3	III
	U 44				340	26	12,6	32,1	76	0,8	III-IV
	U 64				550	44	-	-	-	-	IV
TYPAR	136	Du Pont (F)	Poly-propylene	Melt bonding	136	11	9,2	10,5	50	2,7	II
	200				200	18	10,3	13,2	60	2,6	III

1) Strength in the longitudinal / transverse direction respectively.

2) The penetration number varies between 0 and 5. Low number, good resistance to penetration.

3)

Classification group	I	II	III	IV
Description. (The coarses material adjacent to the fabric is considered.)	No mechanical strength needed For erosion protection and alike.	Separator to clay, silt sand, gravel, peat and march land	Separator to macadam and sorted blasted rock	Separator to unsorted blasted rock

Fig. 6: Classification table for non-woven fabrics to be used in road construction.