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Penetration through geotextiles by riparian plants

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ABSTRACT: To promote the development of vegetation on banks geotextiles used in protection works need to be penetrable for riparian plants like reed and bullrush. In a laboratory experiment a standard test to determine the penetration resistance of geotextiles was developed. In an additional outdoors experiment the penetration through geotextiles by reed shoots was tested. It was found that the penetration through wovens is mainly determined by the penetration resistance of geotextiles and the penetration through non-wovens by the pore size of the geotextile. Based on the results of both experiments criteria were formulated to select geotextiles to be used in ecologically sound bank protection works.

1 INTRODUCTION

Geotextiles are used on a large scale in bank protection works. Applied as a filter they prevent soil particles from being washed out but still allow (ground)water to pass through. When designing the filter the permeability and the pore size are the most important characteristics of the geotextile. To determine these parameters qualified standard methodes are available. However, since the eighties the construction of ecologically sound banks has become the policy of the Dutch government. The government intend to promote the development of bank vegetation and fauna along the main waterways. In bank protection works like these the penetration by riparian plants has become an important characteristic of the geotextile. At present there is no test method available to determine the penetration resistance of geotextiles. Therefore the Road and Hydraulic Engineering Division of the Ministry of Transport, Public Works and Water Management developed a standard method to make it possible for designers and contractors to evaluate and select the right geotextiles to be used in ecologically sound bank protection works.

2 LABORATORY TEST

The development of the test method for penetration resistance was based on two experiments with 35 different types of geotextiles and one riparian plant species, Reed, which is very common throughout the Netherlands. The geotextiles used were selected because they represent the range of available types of geotextiles and are the most commonly used geotextiles in Dutch geotechnical engineering works. The main characteristics of the geotextiles are described in table 1.

2.1 *Test method*

The laboratory test is based on DIN 54307 'Stempeldurchdrückprüfung' (Nieuwsma, *et al.* 1994). A geotextile sample is placed in a cylinder with diameter 150mm. On this sample a cone (fig. 1) is placed, attached to a pressure-box. This cone is made from stainless steel and shaped like a reed shoot to simulate the penetration of a reed shoot through a geotextile. The point of the cone has a diameter of 0.4 mm. The maximum diameter of the cone is 7 mm, and the length is 8 cm. By pressing the cone with a rate of 10 mm per minute through the geotextile sample (fig. 2) the penetration resistance is measured. This is the force F needed to press not only the point of the cone through the geotextile sample but also the cone until the maximum diameter.

2.2 *Penetration resistance forces*

It was found that there were big differences in

Table 1. Summary of the collected data and the main characteristics of the 35 geotextiles. a = shoot penetration after 1 year ($\#/0.75m^2$); b = shoot penetration after 2 year ($\#/0.75m^2$); c = mean shoot length (cm); d = mean shoot diameter (mm); e = pore size (μm); f = weight (g/m^2); g = tensile strength (kN/m) warp; h = tensile strength (kN/m) weft; i = penetration resistance (N).

	a	b	c	d	e	f	g	h	i
Non-wovens									
NW-A	0	0	0,0	0,0	100	360	25	24	59,6
NW-B	8	32	50,3	2,1	99	200	17	19	16,7
NW-C	4	9	39,3	1,6	100	280	17		49,6
NW-D	2	22	49,5	2,7	120	140	8,8		26,4
NW-E	0	0	0,0	0,0	75	350	13	18	56,8
NW-F	0	0	0,0	0,0	70	900	14,8	34,1	107,9
NW-G	0	0	0,0	0,0	80	600	17,3	36,8	97,8
NW-H	7	30	45,3	1,9	90	325	16	18,6	58
NW-I	20	168	55,8	2,3	160	175	4,5	11	24,6
NW-J	50	304	51,2	2,1	170	150	4,4	7,3	17,1
NW-K	1	0	0,0	0,0	80	966	20,2	39,8	192,6
NW-L	3	7	38,1	1,8	100	200	12		41,5
NW-M	11	31	41,0	1,7	105	150	9	9	36,4
Wovens									
W-A	9	20	29,8	2,2	198	185	39	27	13,9
W-B	17	83	57,5	2,2	265	225	44	50	7,2
W-C	18	75	42,9	2,5	200	120	18	18	10,3
W-D	12	64	39,3	1,9	700	210	45	45	9,9
W-E	16	65	51,5	2,3	200	240	68	68	6,3
W-F	24	102	40,4	2,4	250	135	20	25	3,5
W-G	24	100	41,5	2,1	300	165	45	20	5,1
W-H	0	0	0,0	0,0	100	250	70	70	38,9
W-I	6	3	77,0	1,6	145	190	40	36	18,3
W-J	2	16	61,1	1,8	180	100	18	18	7,1
W-K	0	0	0,0	0,0	180	235	45	45	14,8
W-L	3	4	39,5	2,0	450	210	50	40	16,8
W-M	1	4	39,3	1,9	280	530	88	80	25,4
W-N	0	0	0,0	0,0	190	330	55	55	10,2
W-O	14	50	23,5	1,7	1200	190	42	37	11,9
W-P	6	18	32,6	1,5	460	239	54	45	14,9
W-Q	4	5	67,3	1,5	180	187	40	36	17,9
W-R	3	20	33,5	2,3	360	225	54	45	12,2
W-S	0	0	0,0	0,0	65	525	150	150	43,1
W-T	3	9	51,5	1,8	230	233	45	45	16,6
W-U	0	0	0,0	0,0	260	257	54	45	21,6
W-V	0	0	0,0	0,0	250	290	54	45	35,5
ref	116	812	88,4	3,1					

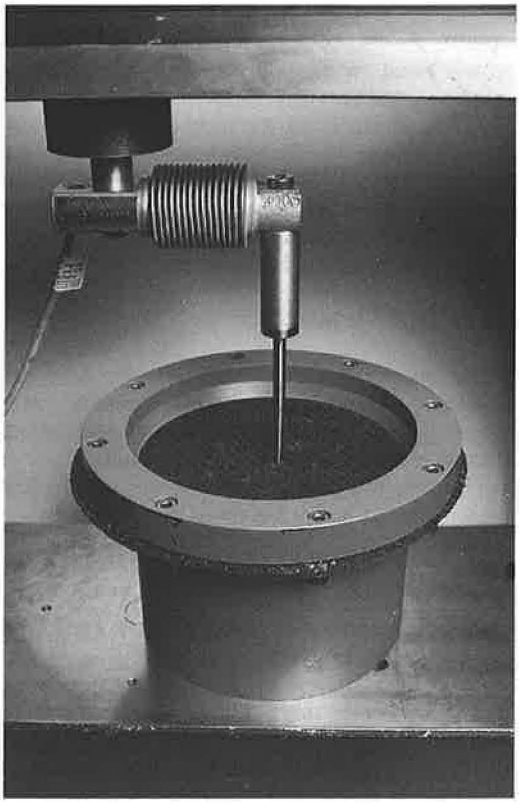

Figure 1. The penetration resistance is measured by pressing a cone through a geotextile sample.

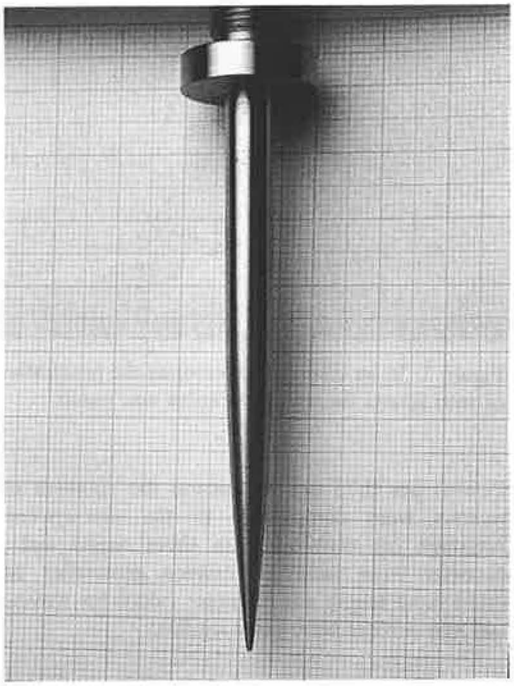

Figure 2. The cone is made from stainless steel and shaped like a reed shoot.

penetration resistance force between samples of one type of geotextile (Ivens & Van den Bol 1994). Nevertheless, also between types of geotextiles big differences were determined. The penetration resistance forces varied from 4 N to 190 N. The relation between the penetration resistance forces and the geotextile characteristics was analysed by a stepwise regression analysis. The geotextile characteristics involved in the analysis were: the type, the weight, the tensile strength, elongation at break, the pore size and the permeability. The results of this analysis showed that the penetration through non-wovens was defined by the weight of the geotextile. The penetration resistance of wovens was best defined by the tensile strength.

3 OUTDOORS EXPERIMENT

To find out if the penetration resistances forces of the geotextiles give an indication of the growth of riparian plants an outdoors experiment was started which lasted two years. In a small artificial pond 108 (35 geotextiles x 3 replicates and three references) glass containers were placed (fig. 3). Each container consisted of two parts. The larger part (50x50x30 cm) was filled with a 30 cm layer of sandy clay. In the soil 5 reed rhizome segments were planted and covered with a geotextile. Thereafter the smaller part (50x50x10 cm) was fixed and a layer of Grauwacke loose stones (80/120 mm) was placed on top. In this way the penetration through the geotextiles by reed shoots was tested. To prevent breaking of the glass caused by frost the containers were set under water during wintertime. All other plants than reed were removed to avoid interference. Throughout the experiment emergent shoots were counted and marked weekly. At the end of the experiment shoot numbers, -diameters, -length, and the biomass of aboveground and underground parts were measured.

3.1 *Shoot penetration*

The number of shoot penetration per geotextile (table 1) varied significantly, from 3 (W-I) to 304

Figure 3. In an outdoors experiment the penetration of reed shoots through geotextiles was tested.

(NW-J) per 0,75 m^2. In general the numbers on wovens were comparable to the non-wovens. Although big differences in shoot length and - diameter were recorded between geotextiles the mean shoot length and diameter values for wovens and non-wovens were quite similar.

Based on the data collected in the field experiment the influence of the different geotextile characteristics on the penetration by reed and the development of the reed plants was analysed by statistical methods. The number of penetrations through wovens is best defined by the weight per m^2. The smaller the weight of the woven-geotextile the larger the number of penetrations one will find. The analysis indicated that for non-wovens the pore size defines the number of shoot penetrations. Non-woven geotextiles with large pore sizes showed larger number of penetrations. The development of the reed shoots (length and diameter) is determined by the tensile strength of the geotextile for both wovens and non-wovens. Shoots will get shorter and thinner when the tensile strength is high. It is not unlikely that in the end shoots will become cut off and die.

4 CORRELATION BETWEEN LABORATORY TEST AND OUTDOORS EXPERIMENT

By analysing the relation between the penetration resistance and the results from the field experiment it became clear wether it is possible to get an indication of the penetration resistance of geotextiles just by using the laboratory test. The results from a stepwise regression analysis showed that the penetration through non-woven geotextiles is best defined by the pore size. It was already possible to estimate the number of penetrations through a non-woven based on the pore size O_{90}. Therefore the laboratory test provided no added value.
However in predicting the number of penetrations through wovens the laboratory test showed to be a worthful method. The penetration resistance of geotextiles gives a more reliable prediction of the number of penetrations than the characteristic weight determined in the field experiment.

5 PREDICTIVE MODELS

Based on the correlation between the field and laboratory experiment predictive models were determined to estimate the number of penetrations through woven and non-woven geotextiles.
For wovens two models were determined. The first model is based on the weight of the geotextile:

$$\sqrt{(N*0.75+0.375)}=4.54-0.01*W$$

where, N = number of penetrations (m^{-2}) and W = geotextile weight (g/m^2).

The reliability of this predictive model is low. A more reliable prediction can be made based on the penetration resistance results. The number of penetrations is defined by:

$$\sqrt{(N*0.75+0.375)}=7.8-2.03*\ln(Ps)$$

where, N = number of penetrations (m^{-2}) and Ps = penetration resistance (Newton).

As mentioned earlier, the number of penetrations through non-wovens can be predicted on the following model:

$$\sqrt{(N*0.75+0.375)}=-3.4+0.06*O_{90}$$

where, N = number of penetrations (m^{-2}) and O_{90} = pore size (μm).

6 THE GROWTH OF BANK VEGETATION IN PRACTICE

Riparian plants like reed are often used to protect banks against erosion caused by waves. On banks like these 6 - 10 reed cuts per m^2 are planted if the reed vegetation on his own, that is without additional stone cover, assures enough protection against erosion. On banks where geotextiles are used as a filter the present vegetation has a more esthetic function (fig. 4). In situations like these no more then 6 reed cuts per m^2 are planted. In a few years time one can already expect a well developed bank vegetation. It is expected that 6 penetrations per m^2 after one growing season give a similar result. This number can be seen as a minimum; geotextiles which show less penetrations are assigned to be too resistent for penetration.

7 EXAMPLE

The design of a bank revetment work requires a reed density of 6 shoots/m^2 after one growing season. Based on this criterion and the predictive models the required geotextile characteristics can be described to achieve this density. Hence, in the protection work a woven geotextile can be used with a maximum weight of 233 gr/m^2 or a maximum penetration resistance force of 15,8 N. When using a non-woven geotextile the minimum pore size has to be 94 μm.
It has to be emphasized that the above mentioned requirements are from the point of view of the ecologist. Obviously one also has to take the hydraulic requirements into account.

8 ACKNOWLEDGEMENTS

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