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# Experiences with "VTT-GEO" Classified Non-Woven Geotextiles for Finnish Road Constructions

# Experiences sur les géotextiles classifiés "VTT-GEO" pour la construction de routes en Finlande

The Geotechnical Laboratory of the Technical Research Centre of Finland has developed a new, the "VTT-GEO" use classification for non-woven geotextiles to be used in road constructions. The principles of this classification system, the six necessary testing procedures for it and the valuation of the ten different criteria are dealt with in detail. Since in autumn 1980 the Finnish Road Board has adopted the new "VTT-GEO" classification for its district organisations' works, non-woven geotextiles are now generally marketed according to the new system. As a condition type-approval tests have to be performed once a year. With a simple field test procedure, based on two of the type-approval tests, the quality of fabrics delivered to the end user can easily be checked. The "VTT-GEO" classification has proved to work well and is of essential aid both for the end user and the producers of geotextiles.

Le laboratoire géotechnique du Centre national de recherches techniques de Finlande a mis au point une nouvelle classification "VTT-GEO" pour des géotextiles non-tissés pour la construction de routes. Les principes de ce système, les six procedés d'essai nécessaires et l'évaluation de dix critères differentes sont traités en détail. La Direction générale de routes en Finlande ayant adopté la nouvelle classification "VTT-GEO" en automne 1980 dans les travaux de ses organisations régionales, les non-tissés sont maintenant généralement vendus selon ce système. De nouveaux essais pour l'approbation du type doivent être effectués une fois par an. Par une simple méthode d'essai sur le terrain, à partir de deux essais pour l'approbation du type, la qualité des matériaux livrés à l'utilisateur peut être contrôlée facilement. La classification "VTT-GEO" a paru fonctionner bien et offre une aide considérable aussi bien à l'utilisateur qu'aux producteurs de géotextiles.

## INTRODUCTION

During the past decade non-woven geotextiles, later in this article also the term fabrics will be used in that sense, have found their use in many applications in civil engineering works in Finland. In the pioneer stage of fabric applications both the users and the representatives of the producers concentrated their main efforts on finding technically and economically advantageous solutions. The nowadays in Finland reached sales level of about 3,5 million m$^2$ (1981) allow to draw the conclusion, that in many cases fabrics have replaced the traditionally of soil materials built up layers, but additionally to these many new applications must have been realized due to the use of fabrics. The most important fabric applications form still permanent and access roads, where the fabric is replacing the traditionally used sand filter layer and is overtaking a filtration and separation function.

Following to the pioneer stage the civil engineering market was flooded with fabrics. Mainly weight and strength specifications were promoted. It was still left to the customer to choose the most suitable product for his specific application. Two aspects, the costs and the announced strength properties, had the main influence on the purchase decisions. Scarcely other aspects, as permeability or filtration properties, were even considered. For different products the given strength values were seldom comparable, due to manysided possibilities for their determination. Some of these test methods obviously were also advantageous for certain types of fabrics.

On behalf of the Nordic Road Federation and under the responsibility of the Norwegian Road Research Laboratory a first classification of fabrics was published in 1977 (1). Based on a fall cone, a CBR-penetration test and on some yet unknown rules of the thumb different products were classified into 4 groups. The table with the so classified products was published in four languages, but until now the basic principles of the group requirements can only be guessed.

In Finland, Sweden and Norway this classification was immediately adopted, as it undoubtedly had the advantage of making real comparisons between different products possible. The earlier on weight limits based requirements were replaced by the fabric groups I...IV. For a short time both producers and their customers could concentrate all their efforts on price negotiations. Clouds appeared soon on the horizon, as new products had to be classified. Lack of information on the classification principles and on the rules of thumb adjusted to these made it impossible to assign the proper group to new products elsewhere but Norway.

## GEOTEXTILE RESEARCH PROJECT AT THE GEOTECHNICAL LABORATORY OF THE TECHNICAL RESEARCH CENTRE OF FINLAND

In 1978 a research project with the working name Quality Control Project was started at the Geotechnical Laboratory of the Technical Research Centre of Finland. Nine producers and the dominating user groups were represented in the project supervision committee. In the first instant it was intended to clear up from a geotechnical and hydraulical point of view, which requirements have to be set to geotextiles at their different applications. Those questions were more thorougly dealt with in the articles ( 3 ) ( 4 ) and finally in ( 6 ) in respect of the long term stability of geotextiles.

In the next stage a minimized set of testing procedures, which in the best way describe the requirements set by practical applications, was invented and recommended for future use. For that purpose comparative tests were performed on a large scale, nowadays used testing methods were analysed and, where necessary, new methods were developed. It could clearly be shown, that depending only on the testing procedure products of different bonding type could suffer unequal treatment. A typical example of such a testing arrangement is the CBR-penetration test, if the test results were interpreted according to the calculation method used at the Norwegian Road Research Laboratory ( 2). In this case the interpretation of the test results is obviously of advantage for thermally bonded products.

With the new test methods, developed by the Geotechnical Laboratory of the Technical Research Centre of Finland, it was attempted to avoid any possible protectionism.

## ON THE LONG TERM STABILITY OF NON-WOVEN GEOTEXTILES IN ROAD CONSTRUCTIONS

The long term properties of non-woven geotextiles, which had been installed into road constructions, were studied in the Nordic countries as a part of a research project of the working group 31 within the Nordic Road Federation. In Finland at 22 different road sites, covering the whole country, geotextiles were recovered by the Finnish Road Board's district organisations and the City of Vaasa. The quality of eight product types from 5 producers could be controlled several years after their installation. Even though the strength properties have undergone serious changes in several cases, it can be stated, that the fabrics have functioned satisfactorily as filter and separator during the controlled life time. These results are described more in detail in the articles (5) and (6).

## PRINCIPAL CONSTRUCTION OF THE VTT-GEO FABRIC CLASSIFICATION

The recovering of the different non-woven fabrics allowed the essential conclusion, that, for fabric applications in permanent structures no remarkable design criteria concerning the stress-strain behaviour of non-woven fabrics can be drawn from the stress state prevailing in the earth structure. For that reason all the strength requirements have to be related to the installation procedure and the technics used at its different stages.

In addition to strength criteria other facts influencing the installation process, like roll width (a product may be delivered folded) and roll weight (rolls of 500 kg weight cannot and due to health regulations for workmen must not be handled by man power only).

Since the majority of the non-woven fabrics for civil engineering purposes available on the market are functioning above all as separator and filter within the earth construction, it is obvious, that also these functions have to be valued in a classification.

In the VTT-GEO classification the fabric properties were therefore valued according to the following key principles. The valuation of different strength properties was assessed to approximately 50 %. The pore structure and its stability, which characterize the filtration properties and the permeability, is judged with a weight of 35 to 40 %. 10- 15 % of the valuation is reserved for production-dependent values, like the uniformity of the product and for such terms of delivering like the roll dimensions and its weight, which finally influence the progress of installation.

The new VTT-GEO classification principles are presented in Table 1. Outside the classification remained still a group of fabric properties, which essentially contribute to the long term stability of the products. Those are UV-radiation resistance, chemical and biological resistance. As a basic requirement the fabrics have to be resistant to all in road constructions usually applied chemicals (as stabilizing agents like lime, fly ash, cement, oil,...), and further they have to resist the attack by bacteria and fungi present in the fabric environment. As these properties depend both on the raw material and on possibly used fixing agents, it seems to be proper to require from the producer side a guarantee concerning the long term stability of the fabric for the specific application in question.

## THE CLASSIFICATION CRITERIA AND THEIR INTERPRETATION

In the VTT-GEO classification the product properties are judged in 10 criteria by aid of a point system. For 8 of these the points are calculated from test results evaluated from 6 classification tests. Two of the criteria are based on optimum modes of delivery, facts which normally are given by the producers.

The THICKNESS of the fabric is measured at a surcharge of $\sigma$=20 kPa on an area of F= 25 cm$^2$ at 3 points over the sample.

The GRAB TENSILE TEST is performed following in principle the procedure of ASTM D 1682 but modified with respect to the width of the fabric specimen and the deformation rate. The width of the sample is 200 mm and the rate of deformation 100 mm/min.

The PLUNGER PULL OUT TEST is performed following the testing procedure developed at the Geotechnical Laboratory of the Technical Research Centre of Finland. In the test a fabric specimen of a diameter $\phi$ 185 mm with a precut, centric hole of 10 mm diameter is clamped horizontally between the specially designed clamping rings fitting to the CBR-cylinder (see Fig. 1).

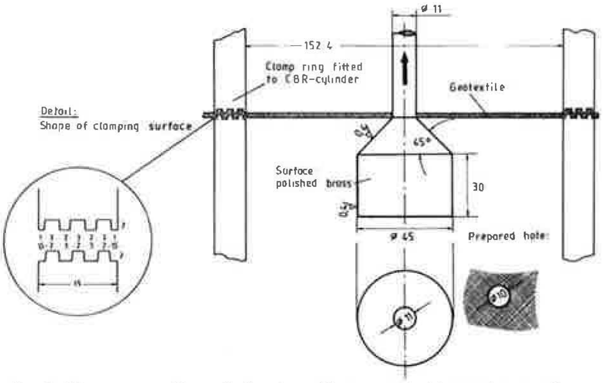



Fig.1 Plunger pull out test. Shape and dimensions of the plunger and the clamping rings.

The to the conical part of the pull-out plunger fixed rod of 11 mm diameter is pulled through the precut hole of the fabric sample and lifted until the fabric surface is touching the plane of intersection between rod and cone. In the test the plunger is pulled through the hole at a constant rate of deformation of 10.8 mm/min. During the test the vertical force acting on the plunger and the corresponding deformation are registered. As test results are listed the maximum force ($P_{max}$) and the corresponding pull length ($h_{max}$), the force measured at a pull length of 20 mm ($P_{20}$) and the vertical component of the

| CRIT. NR. | CLASSIFICATION CRITERIA | UNIT | NUMBER OF TESTS | SAMPLE SIZE mm | WEIGHING FACTOR | REMARKS |
|---|---|---|---|---|---|---|
| | UNIFORMITY TESTS: | | | | | |
| 1 | WEIGHT: $\bar{w}_o$ | $g/m^2$ | 10 | 400 $cm^2$ | $\frac{\bar{w}_o - 100}{20}$ | WEIGHT INCREASE-BENEFIT |
| 2 | WEIGHT VARIATION: s | % | | | $((5/s)-0.5)\times 5$ | LESS THAN 5 % DESIRED |
| | STRENGTH VARIABILITY: GRAB TENSILE TEST IN L AND C DIRECTION | | | | | |
| | TENSILE STRENGTH: $\bar{P}_{max} - s$ | N | 10+10 | 200/200 | $\frac{(\bar{P}_{max}-s)_{strong}}{(\bar{P}_{max}-s)_{weak}} = A$ | A > 1 HOMOGENEITY DESIRED, FACTOR A USED WITH CONE PULL OUT FORCE |
| | THICKNESS: $\bar{t}_o$ (at 20 kPa) | mm | 10 | 25 $cm^2$ | | $\bar{t}_o$ USED WITH POROSITY CRITERIA |
| | STRENGTH TESTS: CONE PULL OUT TEST | | | | | |
| 3 | STRENGTH: $\bar{P}_{max}-s$ | N | 10 | 200/200 | $\frac{(\bar{P}_{max}-s)}{20 \times A}$ | AVERAGE STRENGTH REPRESENTED |
| 4 | $\overline{P_{max} - P_{20}}$ | N | 10 | | $\sqrt{(\overline{P_{max}-P_{20}})-s} - 5$ | AVAILABLE STRESS AFTER INITIAL STRAIN (h = 20 mm) |
| 5 | ELONGATION: $\bar{h}_{max}-s$ | mm | 10 | | $\left(\frac{\bar{h}_{max}-s}{45}\right)^2 \times 20$ | BENEFIT FOR $h_{max}$ >45 mm |
| 6 | FRICTION: $\bar{P}_{clamp}$ | N | 10 | | $\frac{(\bar{P}_{clamp}-s)}{2}$ | TEAR RESISTANCE REFLECTED |
| | PUNCHING AND PERMEABILITY: CONE PENETRATION TEST, WATER SUPPORTED GEOTEXTILE. | | | | | |
| 7 | HOLE SIZE: $\bar{\emptyset} + s$ | mm | 10 | 200/200 | $(\frac{50}{\bar{\emptyset} + s} - 1)\times 5$ | SHOCK TEAR TEST + PERMEABILITY: MAX. 45 POINTS |
| | POROSITY TEST: AIR FLOW RATE AT 0.1 kPa OVERPRESSURE | | | | | |
| 8 | AIR FLOW: $\bar{Q}_{air}$ | $m^3/m^2,s$ | 10 | 10 $cm^2$ | $(2{,}5 \times \sqrt{\bar{Q}_{air}} - \frac{\bar{Q}_{air}}{\sqrt{n \cdot \bar{t}_o}})\times 20$ | LOW AIR FLOW WITH THICK PRODUCTS COMPENSATED MAX. 50 POINTS |
| | WORKABILITY: | | | | | |
| 9 | ROLL WIDTH: (max) b | m | | | $(b\times 2) - 10$ | |
| 10 | ROLL WEIGHT: $W_r$ (NORMAL SIZE, IF NOT SPECIFIED BY THE CUSTOMER). | kg | | | $10 \times \sin(\frac{W_r - 15}{210} \times \pi)$ | AVAILABILITY OF ROLL SIZE CONVENIENT TO HANDLE BY MAN-POWER |

GEOTEXTILE CLASSIFICATION: GROUP REQUIREMENTS

| | CLASSIFICATION GROUP (FOR USE IN ROAD CONSTRUCTION) | POINTS NECESSARY |
|---|---|---|
| 1 | UNCLASSIFIED, NO SPECIAL REQUIREMENTS | ≤ 99,9 |
| 2 | SEPARATOR TO NATURAL SOILS | 100.0...140.0 |
| 3 | SEPARATOR TO MACADAM, SORTED BLASTED ROCK | 140.1...220.0 |
| 4 | SEPARATOR TO UNSORTED BLASTED ROCK | ≥ 220.1 |

Table 1. The principles of the VTT-GEO use classification for non-woven geotextiles to be used as separator and filter in earth constructions.

friction force acting on the cylindrical part of the pull out cone ($P_{clamp}$) (see Fig. 2).

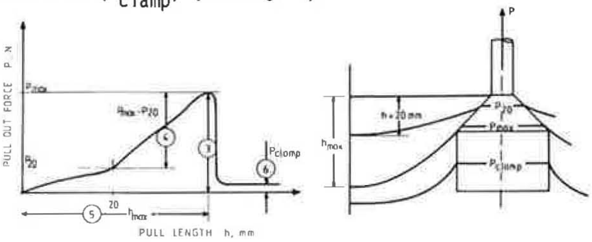



Fig. 2 Plunger pull out test. Interpretation of test results according to the criteria nos. 3..6.

The CONE DROP TEST with water support is in principle performed according to the test procedure described by Alfheim and Sorlie, Paris 1977 (2), but modified with respect to a water support of the fabric specimen clamped into the CBR-cylinder. The CBR-cylinder of a height of 142.5 mm and a volume of 2.6 litres below the fabric is filled up with water until the water level is touching the underside of the fabric sample. In this test the falling cone has to displace an amount of water through the fabric tested, which is equal to that partial volume of the cone which penetrated the sample.

The WEIGHT PER UNIT AREA of the fabric type is determined using samples of size 200 x 200 mm.

The AIR FLOW RATE TEST is performed according to DIN 53 887 using a circular test area of 10 $cm^2$ and a pressure gradient of 100 Pa.

In the following the criteria are briefly interpreted. Also the valuation of each criterion is explained in the sequence of Table 1. The correlations between criteria elements and the evaluation of points are presented in the Figures 4a...d. The relative weights of the main groups of criteria are given in Table 2 for different fabric classes. The calculations were based on the results of tests performed since 1978.

The weight per unit area can hardly be seen as a product property, but its presence as a classification criterion is justified for two reasons. A product with a specific weight greater than that of water can easily be installed on flooded sites compared to floating ones. Obviously this criterion could be of slight advantage to needle punched non-wovens, which normally need more raw material to meet strength requirements equally to termically bonded types, if in the classification only strength properties would be judged.

The WEIGHT VARIATION reflects the homogeneity of the product. As a matter of the production process the materials in question simply cannot be produced without any mass variation, and trimming to minimum variation is probably uneconomic. For the user the inhomogeneity of a product becomes increasingly disadvantageous with increasing mass variation. For these reasons the criterion 2 is given a construction, which is of benefit for homogeneous products, especially for those, which have a weight variation less than 5 %.

The 25 mm GRAB TENSILE TEST is used only to judge the uniformity of the product in respect of its maximum tensile strength. Products may have essential variations in strength properties depending on the direction of testing. For the majority of civil engineering applications obviously only the strength values in the weakest direction will be of advantage for the user. The fabric homogeneity in respect of tensile strength is judged by the homogeneity parameter A ($A \geq 1$), a ratio of the average tensile strength values in two directions, from which the standard deviation has to be deducted. The homogeneity parameter is used with the proper strength criterion no. 3.

The PLUNGER PULL OUT maximum force reflects the force necessary to extend an 11 mm wide hole to a diameter of $\phi$ = 45 mm. The criterion judges the reserve of the geotextile structure to conform with the unevenness of the underground, without successive tear resp. extension of a hole, which forsome reason might have been created during the installation procedure.

The STRENGTH REMAINDER of the plunger pull out test is derived from the pull-out force readings at an initial plunger travel of 20 mm and at maximum. It is a measure for the available strength after an initial strain, which might have been consumed by the installation process.

The ELONGATION criterion is derived from the plunger travel at maximum pull-out force. Fabrics with average "elongation" values exceeding the maximum plunger diameter of 45 mm will gain a slight benefit of the criterion's construction. This built-in advantage is justified by the most positive experiences gained with extensible fabrics in numerous applications. The friction criterion is derived from the vertical component of the clamp force developed during the final stage of the plunger pull out test, where the plunger has practically extended the hole in the fabric sample to a size of $\phi$ = 45 mm and the pulling of the plunger is continued. By aid of this criterion it is possible to judge, to which extent the fabric structure will tolerate the penetration of sharp stones, stumps etc. The clamp force is both depending on the amount and strength of intact fibres around the hole and on the bond strength between the fibres, so the criterion can be looked at as belonging to the group of strength criteria. Nevertheless, the friction criterion is mainly judging the stability of the fabric structure, which will ensure satisfactory performance of the separator and filtration function. For that reason this criterion is grouped together with the following criteria nos. 7 and 8.

The PUNCHING AND PERMEABILITY criterion No. 7 is derived from the hole size in the cone drop test. This test is a modification with a reduced energy input of the one invented by Alfheim and Sorlie (1) (2). At the Norwegian Road Research Laboratory some fabrics had to be tested using a reduced fall height of the cone of 250 mm. Otherwise the test results would have consisted of mainly 50 mm hole sizes. The too high energy input could have been reduced also by changing the weight of the fall cone, the cone angle or diameter of the clamping rings.

Supporting the fabric by water has, besides the energy input reduction, an additional advantage. The falling cone will, immediately after its tip has reached the surface of the fabric, displace a certain amount of water through the pores of the fabric, depending on the penetration depth of the cone. As the cylinder is closed, the water can be discharged only through the pores of the fabric. Thus the test results will be depending on the water permeability of the fabric. The better the discharge capacity of the fabric, the more effectively it can restrain the energy input of the fall cone. A fabric of poor permeability will be lifted upwards by the shock wave of the water, so less restraining the falling cone. This effect will also influence the size of the hole opened by the falling cone. The construction of the criterion is advantageous to small hole sizes, which corresponds to the original Norwegian interpretation of the test results. The criterion judges mainly the separating function of the fabric, but to some extent also its filter function.

The POROSITY of the fabric is judged in the criterion no. 8. It was the ambition not to relate the pore structures of fabric and the soils in contact with the fabric to each other. Fabric filters have generally to be more permeable than the soil material to be filtered, but in principle a 20 times higher water permeability coefficient will be sufficient. The water permeability coefficients of non woven fabrics fulfill this requirement in respect of all those soil materials, to which the application of fabrics might be of benefit. We must not expect miracles from the filter properties of fabrics, and it seems needless to try to dimension the fabric filter according to filter criteria. In cases, where filters built up from soil material, have to be composed of 2 or more layers, it cannot be expected, that a single-layered fabric with more or less uniform pore structure will fulfill similar filter requirements at various stress and strain conditions. In praxis it could be observed, that, but only with static flow conditions, a natural filter cake will be built up in the contact zone between soil and fabric. Together with the fabric structure this filter cake probably will function like a multilayered filter. Dynamic loading conditions will prevent the building up of such a stable natural filter cake behind the fabric. A cake of fines might then appear on top of the fabric, which is a clear sign for misfunctioning of the fabric as filter.

The correlation of test results from water and air permeability tests is generally considered to be poor, but new light was thrown on the matter from comparative tests on compressed fabrics. Ground-installed the fabrics will always be in compressed condition. The water permeability tests, if performed carefully and with de-aired water, are both time consuming and extremely laborious, for which reason the porosity criterion was developed on the basis of the air permeability test. The criterion is composed of two elements, which valuate both the air discharge quantity and the basic parameters of the pore structure of the compressed fabric. By this construction the criterion will ensure, that permeability and porosity of a fabric are kept within reasonable limits.

## FABRIC PROPERTIES LEFT OUTSIDE THE CLASSIFICATION SYSTEM AND PRACTICE FOR THEIR DETERMINATION

A good deal of work can be done, if all the significant fabric properties were tried to determine, and as the branch is developing fast, new research topics will arise all the time. Some of the production parameters may easily be changed, like the composition of fibres, the fibre raw material or the type of bonding. The same production lines, which expel civil engineering fabrics, produce also similar looking products for customers in many other branches. Intensive research work on fabric properties could gain long term advantage, supposed the fabric properties could be linked to the most essential production parameters. Such attempts, even of an independent research institution, were generally refused referring to production secrets.

For that reason the user has to insist on fresh testing certificates given by independent research bodies, on all these properties, which might be important for his application, but remained outside the classification or a type approval system. All facts concerning long term behaviour fall within this group of properties. UV-stability is one of these, though fabrics used for road constructions will seldom be exposed to sunlight over longer periods. Further the producer has to guarantee stability against chemicals generally used in civil engineering works, e.g. stabilizing agents, like lime, cement, oil, fly ash, slag etc.. Fabrics have also to resist biological attacks by bacteria and fungi present in the top soil layers. To clear up these questions suitable test methods have recently been developed. So the user can insist on getting sufficient information on the long term behaviour of the nowadays marked fabrics.

## CHECKING THE FABRIC QUALITY IN THE FIELD

The quality of VTT-GEO classified fabrics can be controlled in the field by two simple testing procedures. These are the plunger pull out test and the fall cone test with water supported fabric samples. Three parallel tests of each type have to be performed. The average values of the two test series form the field acceptance criteria.

I. FALL CONE TEST. The three tests are performed according to the specifications described above. As test result is determined the average hole size opened by the cone.

II. PLUNGER PULL OUT TEST. The plunger is pulled or alternatively pushed through the fabric sample clamped into the CBR-rings. The pull force or pushing force may be applied statically by adding weights, with a constant rate of loading device (e.g. hydraulic jack), but also with a CRS testing machine. The loading principles are shown in Fig. 3.

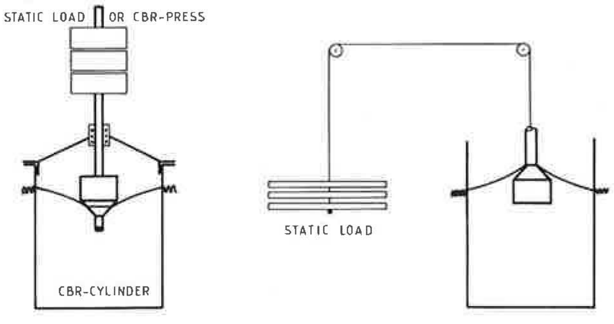



Fig. 3 Plunger pull out test. Alternative loading arrangements for field use.

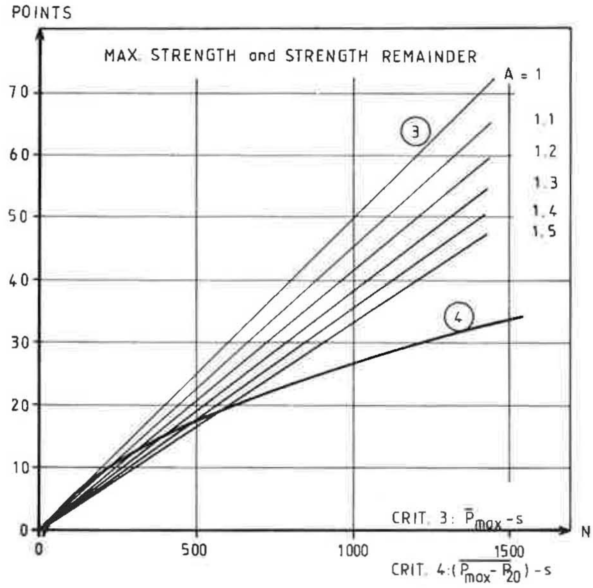
In all cases the required maximum load has to be supplied within 5 minutes. The force requirements for test acceptance have to be determined from the average hole size evaluated from the fall cone tests. In the one case the average maximum force will be reported as the test result,in the alternative case the test gives acceptable results, if the fabric could resist the plunger penetration at the required force level in all the 3 parallel tests. The acceptance criteria for the field tests are given in Tab. 3.

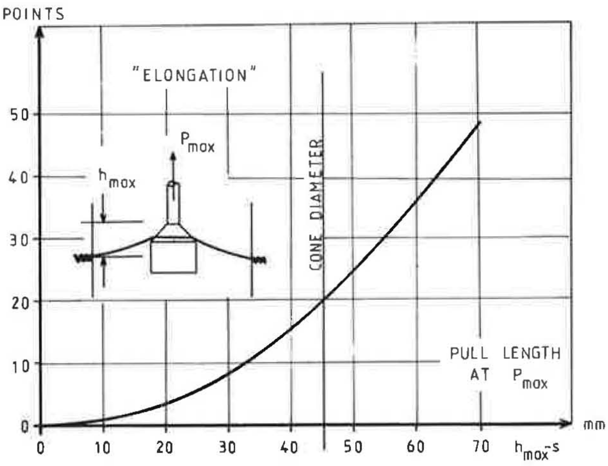
Table 3. Acceptance criteria for the field test series

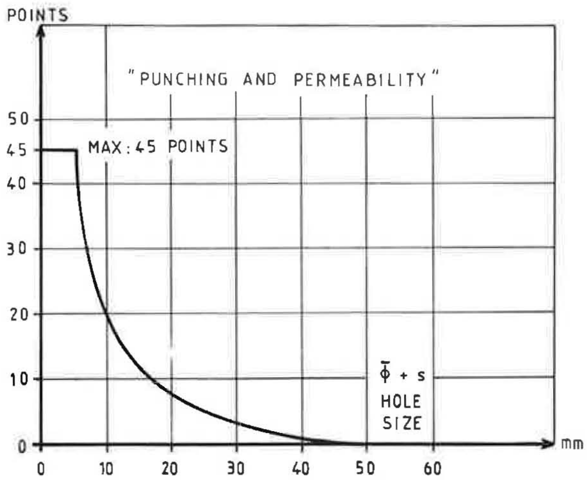
| USE CLASS | ALTERNATIVE PAIRS OF ACCEPTANCE CRITERIA | | | |
|---|---|---|---|---|
| | | I. FALL CONE TEST AVERAGE HOLE SIZE mm | | II. PLUNGER PULL OUT TEST AVERAGE PULL OUT RESISTANCE $\bar{P}_{max}$ kN |
| II | a) | ≤ 20 | and | ≥ 35 |
| | b) | ≤ 25 | and | ≥ 45 |
| | c) | ≤ 30 | and | ≥ 55 |
| | d) | ≤ 35 | and | ≥ 65 |
| III | a) | ≤ 20 | and | ≥ 70 |
| | b) | ≤ 25 | and | ≥ 80 |
| | c) | ≤ 30 | and | ≥ 90 |
| IV | a) | ≤ 20 | and | ≥130 |

## APPLICATION OF THE VTT-GEO CLASSIFICATION IN FINLAND

By the end of the year 1979 the VTT-GEO geotextile classification has been adopted for general use in road constructions. The National Board of Public Roads and Waterways, several purchase departments of cities, companies and organizations require nowadays new testing certificates when inviting tenders for geotextiles on an annual basis. The testing work has generally been performed by the Technical Research Centre of Finland and the following conditions were linked to the application of the VTT-GEO classification. The fabric samples have to be taken from stock of a representative quantity and by an independent person. The testing certificate is valid over a period of one calendar year. If the field tests bring up that the type does not fulfill the class requirements, the complete set of tests has to be carried out for a new type approval.



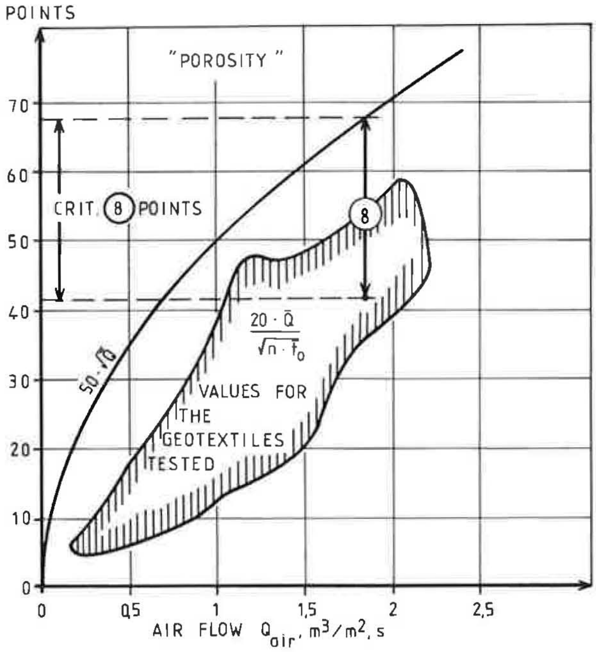




Fig. 4a...d. Correlation between criteria elements and the accumulation of points.

The VTT-GEO classification system has proved to work well during the time it has now been used. Only few reclamations concerning the quality of products delivered to customers were made in cases, where the construction had simply failed. In all cases the geotextiles fulfilled the class requirements, when their quality was controlled with field tests. It could be shown that design faults or unsuitable working methods had caused the failures.

Careful steps were taken to apply the here described classification system also to water constructions. The basic principles seem to work well, though heavier classes and higher point limits are obviously needed. Combined with additional testing procedures, like the BAW (Bundesanstalt für Wasserbau, Karlsruhe, Germany) turbulence test for filtration stability of certain soil types and clearly defined requirements on long term stability, the VTT-GEO classification will serve the demands set to geotextiles for water constructions.

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