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# Comparison Between Different Tensile Tests and the Plunger Puncture Test (CBR Test)

# Comparaison entre différents essais de traction et l'essai de poinçonnement CBR

As an integral part in the preparation of guidelines for the use of geotextiles in Germany, comparative tests with different test methods are carried out on non-woven fabrics. The objective was to select a suitable test method, and led to a programme which systematically evaluated the influence of different sample widths on the result of the strip tensile test. The tensile tests were carried out on two products from each of 8 producers from Germany and abroad. Both mechanically bonded and heat bonded non-wovens were included. The results of the series of tensile tests were statistically evaluated; standard deviation and coefficient of variation of breaking load and extension at break were recorded. The modulus at different load steps was calculated and typical differences between different types of fabric registered. The results were compared with fabric uniformity tests. Correlation with the results of the CBR test (plunger puncture test) commonly used in Germany make comparisons between the various tests possible and allow the selection of a test suitable for the highway engineer.

Dans le cadre le l'établissement d'une notice pour l'emploi de géotextiles on a étudié en République Fédérale d'Allemagne des non-tissés par des essais comparatifs à l'aids de différentes méthodes d'essai. Le but de l'étude a été de choisir une méthode d'essai convenable. Cet objectif a exigéun programme d'essais devant permettre d'explorer systématiquement l'influence de différentes largeurs des bandes de 100 - 600mm sur les resultats de l'essai de traction sur bande. Les essais de traction ont été effectués avec deux produits à chaque fois de huit fabricants du pays et de l'étranger. On a étudié les géotextiles aiguilletés et thermopondés. On a réalisé une exploitation statistique des résultats recus de la serie d'essais de traction. Ont été déterminés, l'écart type et le coefficient de variation de la resistance à la déchirure ainsi que de l'allongement à la rupture. L'étude comprend la définition de le module pour differents niveaux de sollicitation et la présentation de différences typiques constatées entre les différents procédés de fabrication. Les résultats ont également été comparés avec des études de l'homogénéité. Des correlations avec les résultats de l'essai de poinçonnement (CBR) qui est usuel en RFA rendent les differents essais comparables et mènent au choix d'une méthode d'essai practicable en construction routière.

## INTRODUCTION

Guidelines for the use of geotextiles in road construction are being prepared in Germany by a working party of the German Transport and Road Research Institute. During the course of the work, the suitability of standard textile tests for use in highway engineering was called in question. The Norwegians (1) had already answered this question in 1977 with the development of the CBR test, a test tailored to the needs of the highway engineer. Since 1980 this test has been increasingly been used in Germany for control purposes (2). The work described in this paper was intended to compare the results of different tensile tests as regards breaking load, extension at break and load/extension characteristics.

## 1 TEST PROGRAMME

### 1.1 SELECTION OF THE GEOTEXTILES

Only non-wovens were included in the test program on two grounds:

- the use of geotextiles for separation and filtration in highway engineering in Germany is confined almost entirely to non-wovens. Wovens and composite materials are used only in special cases e.g. reinforcement or structure drainage.

- The CBR test cannot be used to compare different types of geotextile (wovens, non-wovens, composites).

Non-wovens currently available can be divided into 2 groups of polymers and 2 of production methods. The principal raw materials are polypropylene (PP) and polyester (PES), production methods heat bonded and mechanical bonded.

First tests with wide samples (3) carried out on a mechanically bonded PES non-woven. In the programme described here, samples from a total of 8 producers were tested, covering all possible raw material/ production method combinations.

Table 1.

| Producer | Product Name | Fibre Raw Mtrl. and Type | Type of Bonding |
|---|---|---|---|
| Hoechst | Trevira Spunb | PES continuous | mechanical |
| ICI Fibres | Terram | PP+PE continuous | heat bonded |
| Chemie Linz | Polyfelt | PP continuous | mechanical |
| Naue Fasert. | Terrafix | PES staple | mechanical |
| Sodoca | Sodoca | PP continuous | mechanical |
| Fibertex | Fibertex | PP staple | heat + mech. |
| Lutravil | Lutradur | PES continuous | heat bonded |
| Du Pont | Typar | PP continuous | heat bonded |

### 1.2 TYPES OF TEST

### 1.2.1 CBR TEST (PLUNGER PUNCTURE TEST)

The CBR test for geotextiles was first described by Alfheim and Sörlie (1), and Wilmers (2) compared the Grab Test with the CBR Test, now standardized in Germany as DIN 54307 E. The non-wovens reported on here were CBR-tested at the Building Materials Testing Station in Wetzlar in accordance with the DIN norm (ring diameter 150 mm, plunger diameter 50 mm, speed of penetration of plunger 60 ± 10 mm/min).

### 1.2.2 TENSILE TESTS

The only standardized German tensile test for non-wovens which records both breaking load and extension is the strip tensile test DIN 53857 Part 2. Gauge length is 200 mm, sample width 50 or 100 mm and crosshead speed 50-200 mm/min. The considerable necking down of non-wovens in this test makes interpretation of their load/extension behaviour a doubtful matter (see (3).

Sissons (4) attempted to exclude the influence of necking by the use of spreader bars (sample size 200 x 200 mm, crosshead speed 20 mm/min). This test is considered rather too complicated in Germany, and the possible influence of the pins on the results has not been fully clarified.

Rigo and Perfetti (3) presented another means of reducing the influence of necking down. In a series of experiments they tested samples of an mechanically bonded polyester non-woven with widths of up to 800 mm, gauge length 100 mm and a crosshead speed of 50 mm/min.

Based on the above information, the following test programme was carried out in the Federal Highway Research Institute (BASt) in Cologne:

- Strip tensile tests in accordance with DIN 53857 Part 2
- tensile tests with 100mm gauge length, sample widths of 100, 200, 300, 400, 500 and 600 mm, and a crosshead speed of 50 mm/min.

### 1.3 SCOPE OF TESTING

For the CBR tests, 10 samples per product were tested (as laid down in DIN 54307 E), this representing a total of 1600 individual tests. The following were measured:-

- sample weight
- push-through force
- extension at 100, 500, 1000 N. push-through, and push-through minus 300 N
- additionally, after exceeding push-through force, extension at push-through minus 300 and 500 N.

At each configuration of the tensile tests, 5 samples per product were tested in machine and cross directions, this respresenting a total of 1280 individual tests. The following were measured:

- sample weight
- max. load
- extension at max. load
- neck down at break

The load/extension curve was plotted mechanically.

## 2 RESULTS

### 2.1 CBR TESTS

The results of the CBR tests which had been carried out by the beginning of March 1982 are presented in the following table.

Table 2.

| Producer | Type | DD [N] | ε [%] 100N | ε [%] DD | Weight [g/m²] |
|---|---|---|---|---|---|
| Hoechst | Tr. Sp. 200 | 2020 | 12 | 69 | 201 |
| | Tr. Sp. 500 | 5152 | 3 | 56 | 509 |
| ICI | Terram 1000 | 1611 | 4 | 35 | 136 |
| | Terram 4000 | 4173 | 2 | 36 | 342 |
| Chemie Linz | Polyfelt TS 500 | 1476 | 7 | 48 | 175 |
| | Polyfelt TS 700 | 2352 | 6 | 48 | 285 |
| Naue | ST 309 | 1793 | 12 | 53 | 362 |
| | ST 509 | 2824 | 8 | 55 | 571 |
| Sodoca | AST 250 | 2090 | 3 | 75 | 281 |
| | AST 420 | 3088 | 4 | 88 | 428 |

Dia. 1 shows the typical shape of the load/deformation curves of a mechanically bonded and a heat bonded continuous filament non-woven in the CBR test.

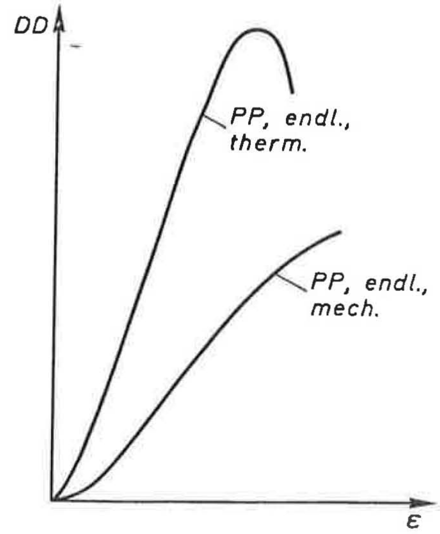

Fig. 1 Load/deformation curves

## 2.2 STRIP TENSILE TESTS

The results of the different tensile tests are shown in tables 3 - 5.

Table 3. Breaking load (kN/m)

| Length [mm] | | | 200 | | 100 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Width [mm] | | | 50 | 100 | 100 | 200 | 300 | 400 | 500 |
| Product | Type | Direction of test | | | | | | | |
| Trevira Spunbond | 200 | mach. | 8,2 | 10,6 | 9,2 | 11,0 | 11,7 | 12,4 | 11,5 |
| | | cross | 12,1 | 12,6 | 12,4 | 12,8 | 14,5 | 14,4 | 14,2 |
| | 500 | mach. | 21,5 | 23,2 | 20,3 | 24,3 | 25,3 | 26,4 | 23,6 |
| | | cross | 24,2 | 26,2 | 20,3 | 29,3 | 22,6 | 32,1 | 29,7 |
| Terram | 1000 | mach. | 6.2 | 8,4 | 7,9 | 9,4 | 9,7 | 9,5 | 9.9 |
| | | cross | 5,6 | 8.0 | 6,9 | 8,9 | 10,0 | 10,7 | 9,9 |
| | 4000 | mach. | 21,9 | 22,8 | 22,9 | 25,9 | 29.2 | 30,3 | 31,0 |
| | | cross | 16,0 | 21,0 | 21,8 | 22,5 | 25,0 | 25,3 | 25,7 |
| Polyfelt | TS 500 | mach. | 8,1 | 8,5 | 9.9 | 10,6 | 9,2 | 10,7 | 10,7 |
| | | cross | 7,8 | 9,3 | 8.8 | 9,4 | 9,7 | 9,8 | 9,6 |
| | TS 700 | mach. | 13,0 | 16,2 | 14,2 | 15,4 | 15,2 | 15,2 | 16,0 |
| | | cross | 16,0 | 16,8 | 17,1 | 16,2 | 16,2 | 15,9 | 17,8 |
| Terrafix | ST 309 | mach. | 3,8 | 4,6 | 3,7 | 4,5 | 5,1 | 4,5 | 5,1 |
| | | cross | 9,5 | 8,6 | 10,0 | 10,9 | 10,7 | 11,2 | 11,7 |
| | ST 509 | mach. | 7,9 | 9,2 | 9,6 | 9,0 | 9,2 | 10,3 | 10,4 |
| | | cross | 13,4 | 14,1 | 15,6 | [illegible] | 16,6 | 17,1 | 17,1 |
| Sodoca | AST 250 | mach. | 10,4 | 11,9 | 11,8 | 11,3 | 12,9 | 11,8 | 13,9 |
| | | cross | 15,4 | 17,0 | [illegible] | 14,0 | 14,0 | 15,9 | 15,4 |
| | AST 420 | mach. | 19,0 | 20,6 | 21,6 | 23,3 | 20,4 | 24,5 | 20,4 |
| | | cross | 21,6 | 22,8 | 26,2 | 25,6 | 23,1 | 25,4 | 25,1 |

Table 4. Extension at break (%)

| Length [mm] | | | 200 | | 100 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Width [mm] | | | 50 | 100 | 100 | 200 | 300 | 400 | 500 |
| Product | Type | Direction of test | | | | | | | |
| Trevira Spunbond | 200 | mach. | 55 | 75 | 79 | 68 | 73 | 75 | 70 |
| | | cross | 58 | 67 | 80 | 64 | 67 | 65 | 63 |
| | 500 | mach. | 56 | 70 | 68 | 63 | 63 | 58 | 59 |
| | | cross | 59 | 66 | 66 | 63 | 58 | 62 | 64 |
| Terram | 1000 | mach. | 25 | 26 | 29 | 27 | 29 | 32 | 22 |
| | | cross | 21 | 27 | 28 | 28 | 28 | 27 | 22 |
| | 4000 | mach. | 24 | 27 | 30 | 32 | 31 | 31 | 31 |
| | | cross | 28 | 25 | 26 | 28 | 28 | 28 | 31 |
| Polyfelt | TS 500 | mach. | 52 | 81 | 98 | 85 | 82 | 89 | 82 |
| | | cross | 31 | 38 | 46 | 42 | 38 | 37 | 37 |
| | TS 700 | mach. | 60 | 75 | 106 | 90 | 86 | 94 | 85 |
| | | cross | 40 | 36 | 59 | 49 | 46 | 44 | 50 |
| Terrafix | ST 309 | mach. | 45 | 76 | 64 | 65 | 60 | 57 | 55 |
| | | cross | 36 | 43 | 32 | 36 | 36 | 35 | 35 |
| | ST 509 | mach. | 54 | 73 | 78 | 72 | 69 | 70 | 67 |
| | | cross | 43 | 47 | 44 | 45 | 38 | 41 | 40 |
| Sodoca | AST 250 | mach. | 81 | 105 | 107 | 83 | 98 | 94 | 105 |
| | | cross | 76 | 81 | 74 | 84 | 79 | 87 | [illegible] |
| | AST 420 | mach. | 78 | 100 | 141 | 111 | 122 | [illegible] | 128 |
| | | cross | 111 | 87 | 124 | 123 | 115 | 116 | 119 |

Table 5, Neck down (mm)

| Length [mm] | | | 200 | | 100 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Width [mm] | | | 50 | 100 | 100 | 200 | 300 | 400 | 500 |
| Product | Type | Direction of test | | | | | | | |
| Trevira Spunbond | 200 | mach. | 12 | 15 | 29 | 132 | 226 | 325 | 423 |
| | | cross | 15 | 13 | 42 | 137 | 228 | 325 | 436 |
| | 500 | mach. | 13 | 25 | 39 | 139 | 232 | 226 | 423 |
| | | cross | 12 | 24 | 41 | 136 | 235 | 226 | 417 |
| Terram | 1000 | mach. | 38 | 83 | 57 | 153 | 253 | 351 | 477 |
| | | cross | 37 | 85 | 57 | 174 | 256 | 360 | 453 |
| | 4000 | mach. | 32 | 87 | 68 | 162 | 272 | 366 | 476 |
| | | cross | 35 | 89 | 76 | 168 | 269 | 371 | 472 |
| Polyfelt | TS 500 | mach. | 12 | 22 | 44 | 130 | 220 | 322 | 424 |
| | | cross | 14 | 29 | 51 | 155 | 245 | 366 | 467 |
| | TS 700 | mach. | 15 | 27 | 59 | 139 | 225 | 304 | 426 |
| | | cross | 17 | 30 | 54 | 155 | 257 | 366 | 416 |
| Terrafix | ST 309 | mach | 18 | 37 | 42 | 132 | 224 | 334 | 441 |
| | | cross | 18 | 36 | 58 | 158 | 249 | 359 | 464 |
| | ST 509 | mach. | 17 | 35 | 44 | 134 | 232 | 323 | 436 |
| | | cross | 19 | 39 | 58 | 145 | 264 | 359 | 464 |
| Sodoca | AST 250 | mach. | 15 | 22 | 40 | 140 | 219 | 332 | 476 |
| | | cross | 13 | 32 | 57 | 142 | 251 | 352 | 448 |
| | AST 420 | mach. | 11 | 31 | 34 | 138 | 222 | 327 | 423 |
| | | cross | 15 | 33 | 24 | 137 | 234 | 340 | 442 |

Dia 2 shows the shape of three typical load/extension curves. To the mechanically and heat bonded fabrics in Dia 1 has been added the curve for a mechanically bonded staple fibre fabric.

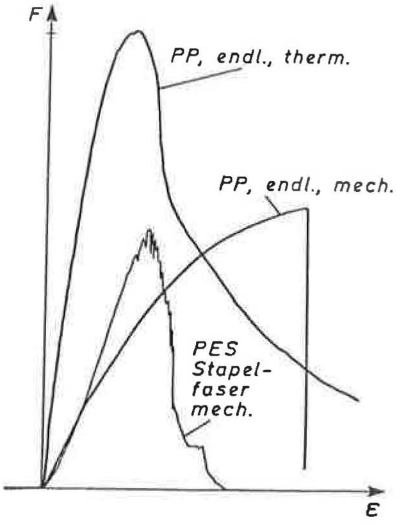

Fig. 2 Load/extension curves.

## 3 EVALUATION

At the time of preparation of this report, mid-March 1982, the testing in the BASt had not yet been completed. Fabrics from five of eight producers had been tested. This evaluation includes the correlation between load and extension for different strip tensile tests and the CBR test. The presentation in Las Vegas will evaluate all eight products.

### 3.1 COMPARISON OF DIFFERENT TENSILE TESTS

The results of the 50 X 200 mm strip test were first correlated with those of the 100 X 100 mm to 500 X 100 mm tests. The correlation coefficients are detailed in Tab. 6.

Table 6.

| Strip [mm] | r $F_R$ | r $\varepsilon_R$ |
|---|---|---|
| 100 × 100 | 0,951 | |
| 200 × 100 | 0,967 | 0,942 |
| 300 × 100 | 0,936 | 0,936 |
| 400 × 100 | 0,958 | 0,938 |
| 500 × 100 | 0,954 | 0,944 |

The correlation coefficients for $F_R$ average over r = 0,953 and, for twenty value pairs, guarantee the existence of a formal relationship. Dia 3 shows this grafically with a plot of the road/extension curves for one product at widths of 100, 300 and 500 mm.

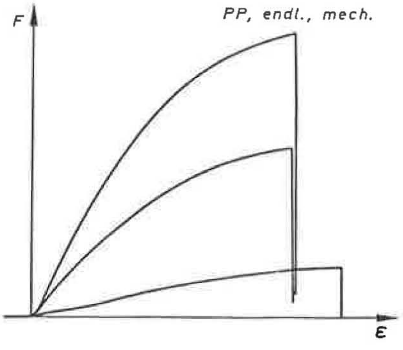

Fig. 3

Analysis of the regression coefficients gives the relationship

$$F_R\ (50x200) = 0,8\ F_R \qquad (1)$$

Dia 4 shows a plot of this relationship.

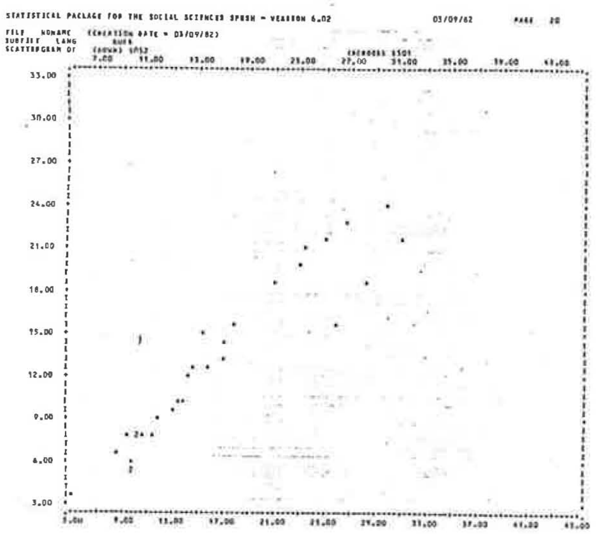

Fig. 4 Relationship Eq. (1)

Similar equations can be formulated to relate the results from different sample widths to one another.

Relating the breaking loads to the fabric weight leads to only a slight alteration in correlation.

The $v_K$ of individual strip tests was calculated for the whole range of fabrics tested. Dia 5 shows that above a sample width of 200 mm, the results of the strip tensile tests are representative for the products in question.

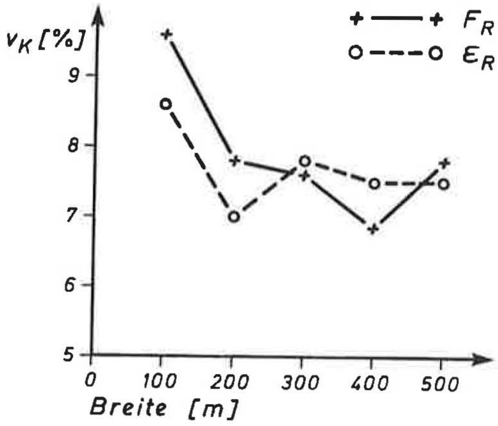

Fig. 5 Variation coefficients

### 4.2 COMPARISON OF THE CBR AND STRIP TENSILE TESTS

The push through force and the extension at push through were correlated with the breaking load and extension at break of strip tensile tests at differing widths and in different test directions (machine and cross).

Table 7.

| Strip [mm] | | r | | |
|---|---|---|---|---|
| | | all | mach. | cross |
| 50 x 200 | $F_R$ | 0,853 | 0,878 | 0,824 |
| | $\varepsilon_R$ | 0,913 | 0,878 | 0,745 |
| 500 x 100 | $F_R$ | 0,886 | 0,826 | 0,951 |
| | $\varepsilon_R$ | 0,874 | 0,253 | 0,925 |

The table indicates a poorer agreement between strip and CBR tests than between different strip tests. The agreement between strip and CBR appears to improve with increasing sample width. Further evaluation of these results is planned for the presentation of the paper.

## 5 CONCLUSIONS

The results discussed here are based on tests on five products which had been evaluated at the time of writing. The inclusion of the remaining three products in the intervening period may lead to alterations and additions at the presentation in Las Vegas.

1. The load/extension behaviour of non-wovens in the CBR test is dependent on the type of bonding. Heat bonded fabrics exhibit a relatively quick load uptake, the extension at push-through is lower, and the breaking point is gradual (not an abrupt tear). The initial extension and the extension at push-through of mechanically bonded fabrics is higher, and they tear abruptly when push-through force is exceeded.
2. The breaking load measured in a tensile test at a certain width can be converted to another width by a multiplication factor. This does not hold true for extension at break. For each product, however, the characteristic load/extension curves for different sample widths are similar and translation from one width to another is possible.
3. As in the CBR test, the load/extension curves of of heat bonded non-wovens in the tensile test exhibit a steeper slope i.e. a higher initial modulus than the mechanically bonded. The work done (the area under the curve) builds up more quickly at first in the case of heat bonded fabrics, but does not attain the value achieved by mechanically bonded geotextiles.

4. A feature of staple-fibre geotextiles are irregularities in the load/extension curves prior to breaking load or push-through force. This suggests that individual groups of fibres are torn or pulled out of the fibre mass.

5. Conversion between CBR and tensile tests is only possible to a limited extent, because of the different stress distribution in the different tests. This is particularly marked in the case of staple-fibre geotextiles.

6. Inhomogeneities in non-wovens have a more pronounced effect on the results of the CBR test than on those of wide width tensile tests.

7. Both types of test should be rated equally when carrying out selection and routine control tests.

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