# CORRELATIONS BETWEEN NONWOVEN POLYPROPYLENE GEOTEXTILE MECHANICAL PROPERTIES

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ABSTRACT: A total of 119 nonwoven polypropylene geotextiles, representing twelve manufacturers and seventeen different product series, were tested for static puncture strength, index puncture resistance, hydraulic burst strength, wide-width tensile strength, grab breaking load, trapezoid tear strength and mass per unit area according to ASTM and/or EN, EN ISO standards. Very good linear correlations were obtained between (a) the three types of out-of-plane deformation tests, (b) the three types of in-plane deformation tests, (c) static puncture strength and wide-width tensile strength and (d) mass per unit area and representative mechanical property tests. In general, the correlation coefficient values were higher than 0.900 and, for 72% of the correlations obtained, were higher than 0.950. The very good to excellent correlations between static puncture strength and/or wide-width tensile strength with other geotextile mechanical properties, strongly supports European Standards practice of defining the requirements for geotextiles in different applications in terms of these two properties. The establishment of correlations between geotextiles properties per manufactured series can result in reduced costs for quality control, quality assurance and specification conformance testing programs.

## 1 INTRODUCTION

The need for quality control, quality assurance and specification conformance testing of geotextiles has been recognized early in the development of these industrial products. Towards the establishment of comprehensive testing programs, pertinent recommendations have been advanced, for example by Koerner and Daniel (1993), Wayne and Christopher (1993), Sprague (1995) and Zanzinger (2000) and appropriate Standards have been adopted such as ASTM D4354 and D4759. However, an internationally accepted protocol for quality control and assurance and conformance testing has not been established yet.

In recent years, European Standards are being developed which define the requirements for geotextiles in different applications, allow manufacturers to describe geotextiles on the basis of declared values for characteristics relevant to the intented use and include procedures for the evaluation of conformity and factory production control. A review of approximately ten such standards indicates that in terms of declared mechanical properties and, indirectly, in terms of quality control testing, European practice prefers wide-width tensile, static puncture (CBR) and dynamic perforation testing. In contrast, there are indications that North American practice prefers grab breaking load, index puncture resistance and trapezoid tearing strength. Such differences not withstanding, the documentation of characteristic values for a large number of mechanical properties requires a very large number of quality control tests. The cost of extensive quality control projects can be reduced if correlations can be established between the different mechanical properties of available geotextiles.

Geotextile properties depend on raw materials (polymer used, fiber type and properties) and on manufacturing processes. Accordingly, the information presented herein is restricted to nonwoven polypropylene geotextiles, since they constitute the strong majority of nonwoven geotextiles. Compiled information on nonwoven geotextile properties may be used to obtain first order approximations between their properties. However, a well known source (GFR 2002) has not yet introduced a column for static puncture test data in the appropriate tables and has removed the column on Mullen (hydraulic) burst strength following recommendations for gradually phasing this test out of active usage (DeBerardino 1994, Kinney 2000). Furthermore, no wide-width strength data are given for any of the 132 nonwoven polypropylene geotextiles listed and mass per unit area is reported only for 35% of them.

As an alternative to a source of compiled information, property values directly available from geotextile manufacturers may be utilized to investigate possible correlations. Technical data sheets posted on the web sites of 16 manufacturers were used to obtain information on the physical and mechanical properties of 222 different nonwoven polypropylene geotextiles (needle-punched, heat-bonded, post-treated). Static puncture strength values were reported for 75% of the geotextiles. Wide-width tensile strength values were reported for 49% of the geotextiles for both directions (machine, cross-machine) and for 26% for one direction only. As stated by the manufacturers, the property values given were minimum average roll values, typical, average from a large number of tests, and mean minus standard deviation. Accordingly, overall correlations or correlations per manufacturer would be based on different types of data, both qualitatively and quantitatively, reducing significantly the practical value of such correlations.

Past experimental efforts, for example by Moritz and Murray (1982), Cazzuffi et al. (1986), Koerner et al. (1986), Richards and Scott (1986), Frobel and Montalvo (1993), Montalvo and Sickler (1993), and Agosti et al. (2000) investigated correlations between various mechanical properties of nonwoven geotextiles (wide-width tensile strength, grab breaking load, trapezoid tearing strength, static puncture strength, index puncture resistance, burst strength) as well as between mechanical properties and mass per unit area. However, only a limited number of products, ranging from 3 to 17, were tested as part of each investigation. Atmatzidis and Chrysikos (2000, 2002) reported correlations of the burst strength and the static puncture strength with other mechanical and physical properties for a significantly larger number of nonwoven polypropylene geotextiles.

The observations on the need for cost-efficient quality control testing, the limited documentation of correlations between mechanical and/or physical properties and the deficiency of available technical data, provided the impetus for the experimental investigation reported herein.

## 2 MATERIALS AND EXPERIMENTAL PROCEDURES

For the purposes of the experimental investigation reported herein, samples of nonwoven polypropylene geotextiles were obtained from twelve different European and North American manufacturers. The size of the samples ranged from 4m$^2$ to 12m$^2$ with a width equal to the standard production roll width of each manufacturer. Some manufacturers provided samples covering two different groups of their products. The number of different geotextiles provided (number of grades per product series) ranged from three to ten, yielding a total of 119 samples for testing. The geotextiles tested were needle-punched (82%) and heat-bonded (18%) products and were made of continuous or staple filaments. Some needle-punched products were post-treated (thermal surface treatment on one or both sides). In order to avoid the use of commercial names, a generic notation (M1 through M17) is used to identify products and manufacturers. Numbers in parenthesis next to an identification code, i.e. M1(9), indicate the number of different geotextile grades in that series.

All geotextiles were tested for wide-width tensile strength (ASTM D4595, EN ISO 10319), grab breaking load (ASTM D4632), trapezoid tearing strength (ASTM D4533), static puncture -CBR-strength (ASTM D6241, EN ISO 12236), index puncture resistance (ASTM D4833), hydraulic -Mullen-burst strength (ASTM D3786) and mass per unit area (ASTM D5261, EN 965). All tests were conducted under standard laboratory conditions using the number of specimens specified by each standard. The equipment used to conduct hydraulic burst strength tests was constructed in house and meets all the specifications set by ASTM Standard D3786 (Atmatzidis and Chrysikos 2000). A computer controlled constant-rate-of-traverse loading frame was used to conduct all other mechanical property tests. Mass per unit area was measured on the specimens used for wide-width tensile testing.

## 3 RESULTS AND DISCUSSION

The results obtained for each series of geotextiles tested, were used in order to obtain correlations between (a) “out-of-plane” deformation tests, that is between static puncture strength, Fp, (in N), index puncture resistance, $F_i$, (in N) and hydraulic burst strength, P, (in kPa), (b) “in-plane” deformation tests, that is between wide-width tensile strength, $a_f$, (in kN/m), grab breaking load, $F_g$, (in N) and trapezoid tearing strength, $F_t$, (in N), (c) “in-plane” and “out-of-plane” deformation tests and (d) between mechanical property tests and mass per unit area, M, (in g/m$^2$). As a first order approximation, a linear relationship was used with the constrain that the line passes through the origin of the axes in order to avoid disadvantages in terms of physical interpretation. Similarly, linear correlations were obtained for the complete set of data and for groups of data (i.e. needle-punched, heat-bonded geotextiles).

All geotextiles tested exhibit some degree of anisotropy as well as differences in tensile strength and elongation at failure between the machine and cross-machine directions. Along the machine direction, tensile strength and elongation at failure ranged from 3.1 kN/m to 75.1kN/m and from 20% to 43%, respectively, while in the cross-machine direction they ranged from 3.0 kN/m to 148.2 kN/m and from 22% to 98%, respectively. A number of geotextiles (11%) exhibited less than 5% difference in strength between the machine and the cross-machine directions while 25% exhibited less than 5% difference in elongation at failure between the two directions of testing. Marked differences were measured for the rest of the geotextiles. Accordingly, for in-plane deformation tests, correlations were obtained along both directions (MD and CD).

Correlations between in-plane and out-of-plane deformation tests can be affected by the degree of anisotropy exhibited by the geotextiles. During out-of-plane tests, the average elongation is the same along any direction while the load or stress causing elongation varies with direction. Accordingly, correlations of out-of-plane with in-plane deformation tests could be obtained in terms of the strength along the MD or CD direction or along the weaker or stronger direction. Best correlations, in terms of correlation coefficient values, were obtained when the average of the strength along the MD and CD directions was employed. Only such correlations are presented herein.

### 3.1 *Correlations between out-of-plane deformation tests*

Static puncture (CBR) strength was correlated to index puncture resistance and hydraulic burst strength and the results are presented in Table 1 and Figures 1 and 2. It should be noted that there is a significant difference in size between specimen for static puncture tests and specimen for index puncture and burst strength (150mm, 45mm, 30mm diameter, respectively). However, these differences do not have an impact on the correlations obtained. The linear correlation between static puncture strength and index puncture resistance appears to be very good in terms of correlation coefficient, $R^2$, which attains values ranging from 0.939 to 0.996, with $R^2$=0.931 when the complete set of date is fitted by a linear function. Very good to excellent correlations were also obtained for the data groups representing the 97 needle-punched and the 22 heat-bonded products (0.921 and 0.971, respectively). Using the overall proportionality ratio (0.184) the index puncture resistance of each geotextile was computed in terms of the measured static puncture strength and the result was compared with the measured value. The resulting error ranged between ±15% and between ±25% for 60% and 95% of the geotextiles, respectively. As expected, when the proportionality

Table 1 Correlations between out-of-plane deformation tests

| Geotextile Series | $P=A\,F_p$ | | $F_i=A\,F_p$ | |
|---|---|---|---|---|
| | A | $R^2$ | A | $R^2$ |
| M1 (9) | 1.005 | 0.962 | 0.208 | 0.965 |
| M2 (7) | 0.928 | 0.969 | 0.209 | 0.985 |
| M3 (10) | 0.927 | 0.964 | 0.223 | 0.961 |
| M4 (10) | 0.957 | 0.936 | 0.200 | 0.967 |
| M5 (4) | 0.887 | 0.968 | 0.222 | 0.980 |
| M6 (6) | 0.827 | 0.987 | 0.171 | 0.959 |
| M7 (6) | 1.002 | 0.978 | 0.208 | 0.985 |
| M8 (8) | 0.924 | 0.933 | 0.202 | 0.943 |
| M9 (4) | 0.881 | 0.982 | 0.201 | 0.996 |
| M10 (4) | 0.883 | 0.999 | 0.210 | 0.996 |
| M11 (3) | 0.919 | 0.997 | 0.198 | 0.991 |
| M12 (10) | 0.902 | 0.943 | 0.197 | 0.967 |
| M13 (9) | 0.876 | 0.968 | 0.177 | 0.972 |
| M14 (7) | 0.782 | 0.756 | 0.154 | 0.939 |
| M15 (10) | 0.880 | 0.952 | 0.178 | 0.978 |
| M16 (6) | 0.872 | 0.951 | 0.172 | 0.984 |
| M17 (6) | 0.942 | 0.988 | 0.204 | 0.993 |

$F_p$: static puncture strength (N)
$F_i$: index puncture resistance (N)
P: hydraulic burst strength (kPa)

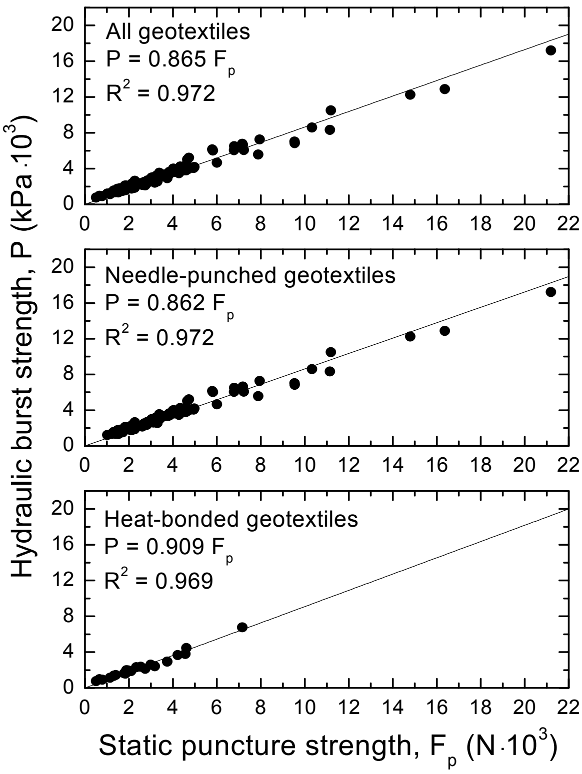


Figure 1 Correlations between static puncture strength and hydraulic burst strength

ratio obtained for each specific geotextile series was used, the resulting error for the prediction of the index puncture resistance was ±10% and ±15% for 75% and 90%, respectively, of the geotextiles.

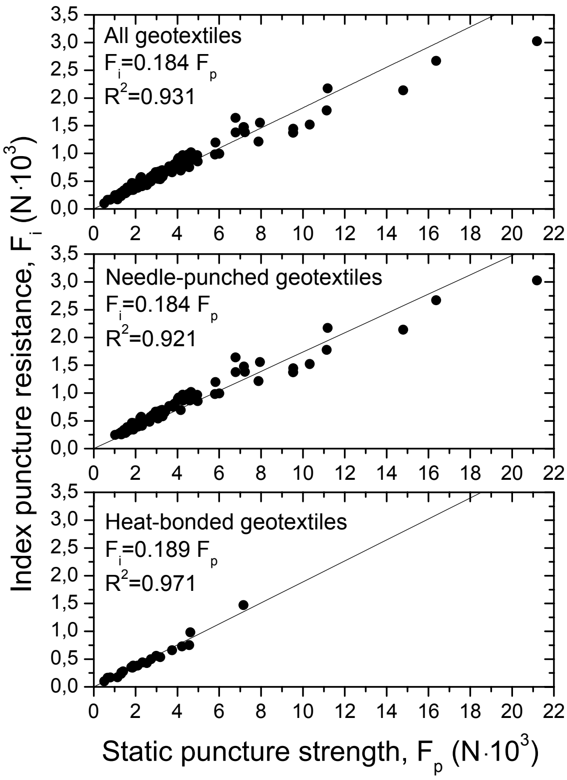


Figure 2 Correlations between static puncture strength and index puncture resistance

The linear correlations between static puncture strength and hydraulic burst strength appear to be equally good. The values of the correlation coefficient, $R^2$, range from 0.933 to 0.999 (with only one exception, that of series M14 with $R^2$=0.756) with $R^2$=0.972 when the complete set of data is fitted by a linear function. Excellent correlations were also obtained for the data groups representing the 97 needle-punched and the 22 heat-bonded products (0.972 and 0.969, respectively). Using the overall proportionality ratio (0.865) the burst strength of each geotextile was computed in terms of the measured static puncture strength and the result was compared to the measured value. The resulting error ranged between ±5%, ±10% and ±20% for 30%, 55% and 85%, respectively, of the geotextiles. When the proportionality ratio obtained for each specific geotextile series was used, the resulting error for the prediction of the burst strength was ±5% and ±15% for 45% and 85%, respectively, of the geotextiles.

In general, index puncture resistance and hydraulic burst strength exhibit very good to excellent correlations with static puncture strength. Since the latter is a performance oriented test, it can be considered as representative of the behavior of nonwoven polypropylene geotextiles in out-of-plane deformation conditions and can be selected in order to obtain correlations with other mechanical and/or physical properties of the geotextiles.

### 3.2 *Correlations between in-plane deformation tests*

Wide-width tensile strength was correlated to grab breaking load and trapezoid tear resistance and the results are presented in Table 2 and Figures 3 and 4. It should be noted that significant differences exist between these three tests in terms of specimen size and shape, deformation rate and scope of testing. However, these differences appear to have only a small impact on the correlations obtained. In terms of correlation coefficient values, $R^2$, the linear correlations between grab breaking load and wide-width tensile strength appear to be very good, for both MD and CD directions, since they range from 0.884 to 0.997 with 80% of them being over 0.950. However, the corresponding proportionality ratios, A, cover a rather wide spectrum, ranging from 44.4 to 85.9. Accordingly, when the overall proportionality ratios (70.89 and 64.25 for MD and CD directions, respectively) one used to predict grab

Table 2 Correlations between in-plane deformation tests

| Geotextile Series | $F_g$=A·$a_f$ | | | | $F_t$=A $a_f$ | | | |
|---|---|---|---|---|---|---|---|---|
| | MD | | CD | | MD | | CD | |
| | A | $R^2$ | A | $R^2$ | A | $R^2$ | A | $R^2$ |
| M1 (9) | 49.57 | 0.988 | 49.08 | 0.990 | 20.54 | 0.682 | 22.48 | 0.795 |
| M2 (7) | 60.38 | 0.996 | 55.72 | 0.992 | 24.24 | 0.987 | 24.91 | 0.985 |
| M3 (10) | 70.40 | 0.964 | 53.37 | 0.976 | 31.58 | 0.981 | 26.72 | 0.982 |
| M4 (10) | 55.87 | 0.984 | 53.48 | 0.979 | 23.90 | 0.976 | 25.29 | 0.965 |
| M5 (4) | 56.06 | 0.961 | 44.41 | 0.987 | 28.26 | 0.879 | 22.92 | 0.978 |
| M6 (6) | 64.40 | 0.973 | 62.18 | 0.980 | 29.27 | 0.996 | 28.66 | 0.988 |
| M7 (6) | 59.62 | 0.979 | 57.47 | 0.994 | 22.31 | 0.912 | 23.89 | 0.983 |
| M8 (8) | 59.27 | 0.957 | 56.85 | 0.992 | 24.09 | 0.964 | 25.30 | 0.965 |
| M9 (4) | 53.41 | 0.901 | 49.40 | 0.936 | 24.42 | 0.937 | 22.02 | 0.816 |
| M10 (4) | 79.18 | 0.971 | 68.72 | 0.993 | 29.60 | 0.341 | 29.36 | 0.987 |
| M11 (3) | 66.25 | 0.993 | 59.49 | 0.997 | 35.20 | 0.920 | 31.20 | 0.986 |
| M12 (10) | 64.60 | 0.966 | 63.33 | 0.968 | 19.14 | 0.850 | 19.74 | 0.770 |
| M13 (9) | 60.90 | 0.890 | 58.88 | 0.957 | 29.48 | 0.914 | 25.18 | 0.891 |
| M14 (7) | 86.51 | 0.920 | 85.88 | 0.884 | 32.21 | 0.880 | 31.92 | 0.875 |
| M15 (10) | 82.18 | 0.993 | 82.97 | 0.993 | 28.08 | 0.726 | 22.74 | 0.821 |
| M16 (6) | 74.44 | 0.933 | 75.55 | 0.953 | 27.09 | 0.757 | 27.89 | 0.875 |
| M17 (6) | 69.03 | 0.990 | 74.11 | 0.938 | 22.09 | 0.981 | 24.19 | 0.925 |

MD: machine direction CD: cross-machine direction
$a_f$: wide-width tensile strength (kN/m)
$F_g$: grab breaking load (N)
$F_t$: trapezoid tear strength (N)

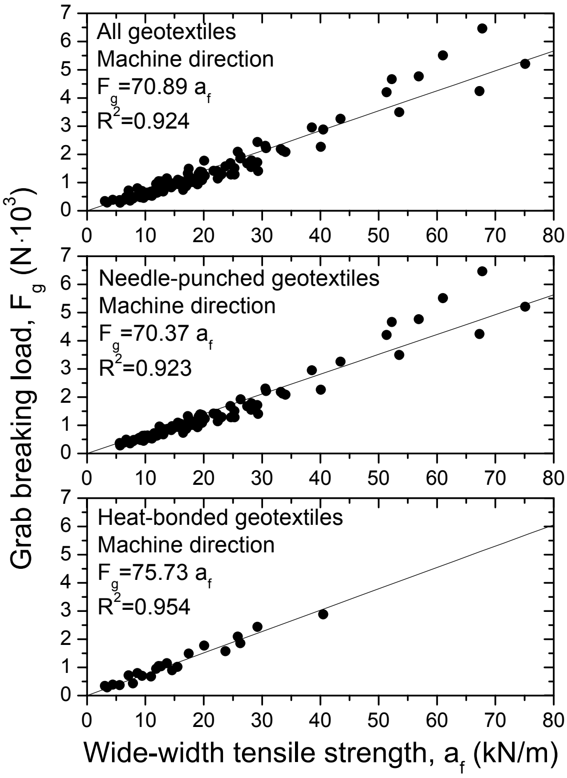


Figure 3 Correlations between wide-width tensile strength and grab breaking load

breaking load from measured wide-width tensile strength, the resulting error is considered large (±15% and ±40% for 41% and 83% of the geotextiles). On the contrary, when the proportionality ratio obtained for each specific geotextile series is used, the resulting error in predicting grab breaking load values is significantly reduced to ±5% and ±20% for 40% and 95%, respectively, of the geotextiles.

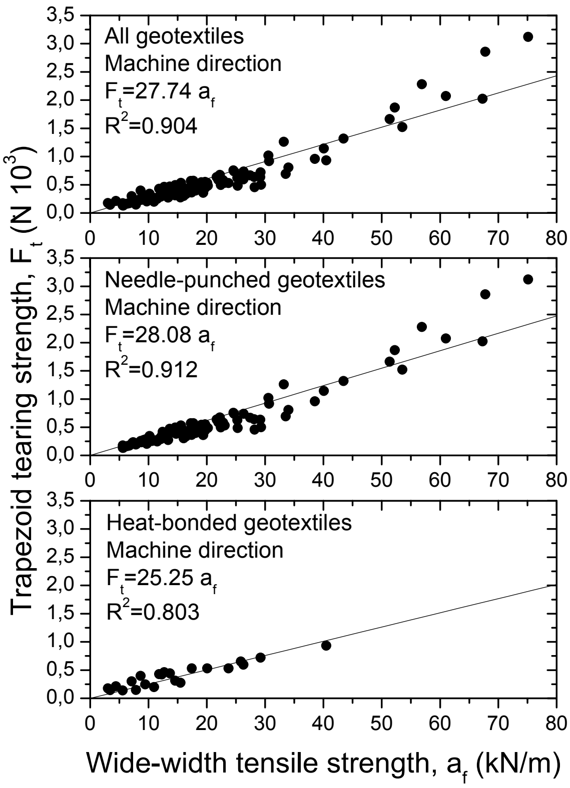


Figure 4 Correlations between wide-width tensile strength and trapezoid tearing strength

The correlations between trapezoid tearing strength and wide-width tensile strength are, qualitatively, inferior to those obtained between grab breaking load and wide-width tensile strength. The values of the correlation coefficient, $R^2$, range from 0.682 to 0.996 with 50% of them being over 0.950. Similarly, the corresponding proportionality ratios, A, have a ratio of 1:1.75 between minimum and maximum values (approximately 20 to 35). Accordingly, when the overall proportionality ratios (27.74 and 27.18 for MD and CD directions, respectively) are used to predict tearing strength from measured wide-width tensile strength, the results are rather poor. An error of ±5% and ±20% is observed for 16% and 69%, respectively, of the geotextiles. However, when the proportionality ratio obtained for each specific geotextile series is employed, the resulting error is significantly reduced to ±5% and ±20% for 37% and 85%, respectively, of the geotextiles.

Although there are significant differences between these three mechanical property tests, there are strong indications that very good correlations can be established per specific geotextile series. Since the wide-width tensile test is a performance oriented test, it can be considered representative of the behavior of nonwoven polypropylene geotextiles in in-plane deformation conditions and can be selected in order to obtain correlations with other mechanical and/or physical properties of geotextiles.

### 3.3 *Correlations between static puncture and wide-width tensile strength*

Pursuant to the observations made in the foregoing paragraphs, correlations were obtained between the static puncture strength and the wide-width tensile strength (represented by the average of the strength along the machine and cross-machine directions). The results obtained are shown in Table 3 and Figure 5. This linear correlation is excellent in terms of the correlation coefficient, $R^2$, which attains values ranging from 0.950 to 0.995, with $R^2$=0.977 when the complete set of data is fitted by a linear function. The proportionality ratio between static puncture strength and average wide-width tensile strength ranges from 152.9 to 199.9 and is equal to 171.4 for the complete set of data. Using the overall proportionality ratio, the static puncture strength of each geotextile was computed in terms of the

Table 3 Correlations between static puncture strength and wide-width tensile strength

| Geotextile Series | $F_p$=A $a_{f,av}$ | |
|---|---|---|
| | A | $R^2$ |
| M1 (9) | 155.1 | 0.993 |
| M2 (7) | 183.7 | 0.956 |
| M3 (10) | 171.0 | 0.972 |
| M4 (10) | 158.8 | 0.950 |
| M5 (4) | 166.5 | 0.969 |
| M6 (6) | 180.4 | 0.973 |
| M7 (6) | 155.6 | 0.970 |
| M8 (8) | 157.7 | 0.960 |
| M9 (4) | 180.1 | 0.993 |
| M10 (4) | 155.9 | 0.995 |
| M11 (3) | 155.0 | 0.967 |
| M12 (10) | 173.7 | 0.984 |
| M13 (9) | 165.1 | 0.971 |
| M14 (7) | 178.4 | 0.982 |
| M15 (10) | 152.9 | 0.997 |
| M16 (6) | 186.7 | 0.976 |
| M17 (6) | 199.9 | 0.982 |

$F_p$: static puncture strength (N)
$a_{f,av}$: average wide-width tensile strength (kN/m)

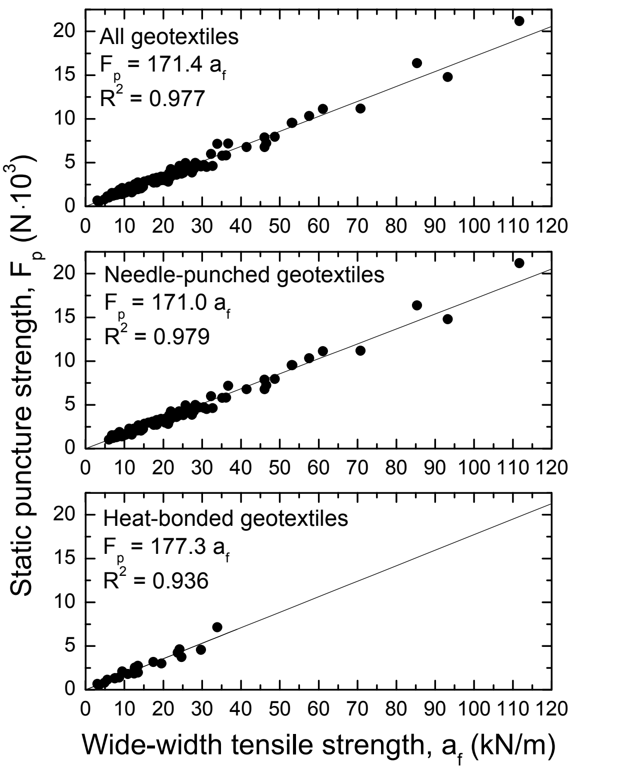


Figure 5 Correlations between static puncture strength and average wide-width tensile strength

measured average wide-width tensile strength and the result was compared with the measured value. The resulting error ranges between ±5%, ±10% and ±20% for 34%, 57% and 93%, respectively, of the geotextiles tested. As expected, when the proportionality ratio obtained for each specific geotextile series is used, the resulting error is less than ±5% for 50% of the geotextiles and less than ±15% for 95% of the geotextiles. Accordingly, it can be stated that the average tensile strength obtained by wide-width tests along the MD and CD directions can be used with confidence in order to predict the static puncture strength of nonwoven polypropylene geotextiles.

### 3.4 *Correlations with mass per unit area*

It is of interest to investigate the possibility of correlating basic mechanical properties, such as the static puncture strength and the wide-width tensile strength, with a basic physical property, such as the mass per unit area. The information presented in Table 4 indicates that, with the exception of geotextile series M14, excellent correlations exist between static puncture strength and mass per unit area when each geotextile series is examined individually (correlation coefficient range from 0.938 to 0.998). Similarly excellent correlations, for both the machine and cross-machine directions, exist between wide-width tensile strength and mass per unit area in terms of individual geotextile series (correlation coefficient range from 0.926 to 0.997). It can also be observed that the proportionality ratio, A, obtained for three geotextile series (M10, M11 and M14) for correlations of mass per unit area with either static puncture of wide-width tensile strength, has values which are significantly different than the values obtained for all the other geotextile series. As shown in Figures 6 and 7, when the data of these three geotextile series are excluded from the overall set of data obtained for needle-punched geotextiles, the resulting overall correlations are significantly improved. A closer look at the information presented in Tables 1, 2 and 3 reveals that these three

Table 4 Correlations with mass per unit area

| Geotextile Series | $F_p$=A·M | | $a_f$=A·M MD | | $a_f$=A·M CD | |
|---|---|---|---|---|---|---|
| | A | $R^2$ | A | $R^2$ | A | $R^2$ |
| M1 (9) | 9.80 | 0.983 | 0.0592 | 0.969 | 0.0670 | 0.934 |
| M2 (7) | 11.14 | 0.987 | 0.0553 | 0.948 | 0.0650 | 0.956 |
| M3 (10) | 10.89 | 0.976 | 0.0494 | 0.942 | 0.0777 | 0.943 |
| M4 (10) | 11.17 | 0.938 | 0.0653 | 0.968 | 0.0754 | 0.986 |
| M5 (4) | 11.40 | 0.989 | 0.0452 | 0.976 | 0.0916 | 0.988 |
| M6 (6) | 10.09 | 0.974 | 0.0481 | 0.994 | 0.0727 | 0.985 |
| M7 (6) | 9.66 | 0.990 | 0.0539 | 0.966 | 0.0657 | 0.945 |
| M8 (8) | 10.54 | 0.978 | 0.0541 | 0.936 | 0.0793 | 0.979 |
| M9 (4) | 11.61 | 0.998 | 0.0543 | 0.943 | 0.0744 | 0.981 |
| M10 (4) | 6.75 | 0.998 | 0.0403 | 0.975 | 0.0604 | 0.947 |
| M11 (3) | 6.20 | 0.968 | 0.0273 | 0.993 | 0.0527 | 0.997 |
| M12 (10) | 11.06 | 0.968 | 0.0629 | 0.947 | 0.0641 | 0.926 |
| M13 (9) | 11.72 | 0.973 | 0.0693 | 0.916 | 0.0723 | 0.975 |
| M14 (7) | 8.41 | 0.345 | 0.0473 | 0.820 | 0.0487 | 0.740 |
| M15 (10) | 10.68 | 0.972 | 0.0701 | 0.962 | 0.0695 | 0.971 |
| M16 (6) | 11.58 | 0.979 | 0.0615 | 0.932 | 0.0635 | 0.951 |
| M17 (6) | 12.97 | 0.982 | 0.0743 | 0.982 | 0.0553 | 0.942 |

MD: machine-direction CD: cross-machine direction
$F_p$: static puncture strength (N)
$a_f$: wide-width tensile strength (kN/m)
M: mass per unit area (g/m$^2$)

geotextile series exhibited, in general, abnormally high or low proportionality ratio values and/or low correlation coefficient values. It is noted that the geotextiles in groups M10, M11 and M14 constitute a second series of geotextiles produced by their manufacturers. Although they are needle-punched geotextiles, possible differences in fiber quality and manufacturing processes yield significant differences in performance. Accordingly, caution should be exercised when data on mass per unit area are combined to obtain overall correlations with mechanical properties.

## 4 CONCLUSIONS

Based on the results obtained and the observations made during the experimental investigation reported herein, the following conclusions may be advanced which apply to

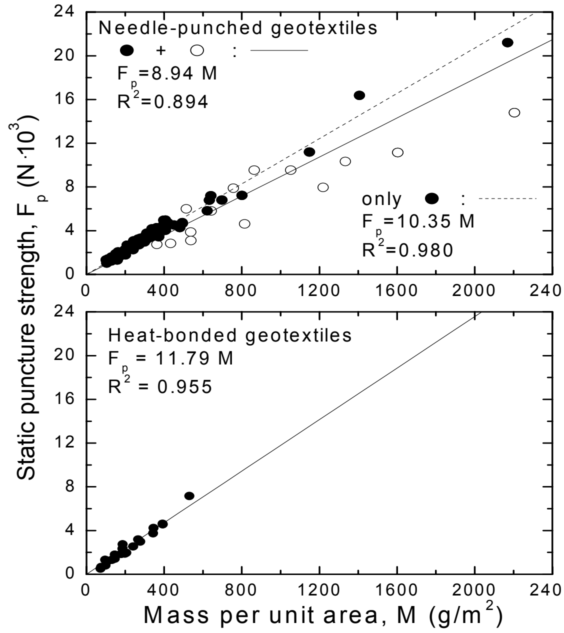


Figure 6 Correlations between static puncture strength and mass per unit area

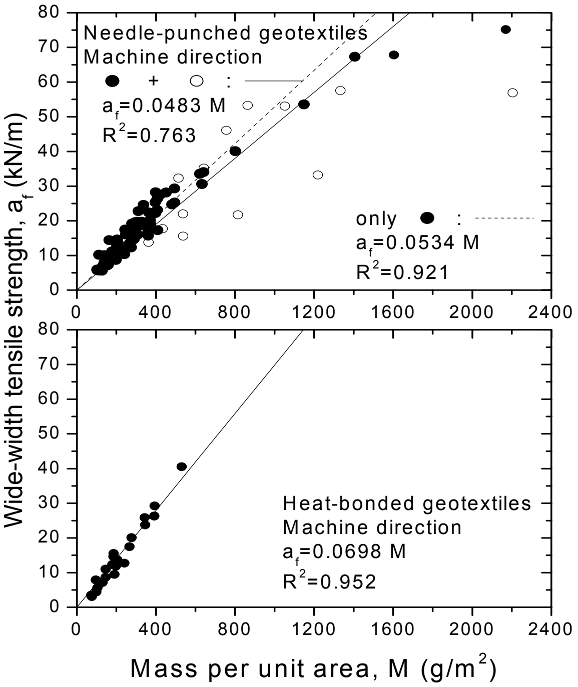


Figure 7 Correlations between wide-width tensile strength and mass per unit area

nonwoven polypropylene geotextiles containing no recycled or low quality raw materials:

1. Very good to excellent linear correlations exist between the most frequently tested mechanical properties for quality control, quality assurance and specification conformance.
2. Static puncture strength, index puncture resistance and hydraulic (Mullen) burst strength are equally good indicators of geotextile performance in out-of-plane deformation conditions. Since hydraulic burst testing of small size specimens is being phased out, static puncture strength appears to have a dominant position as a performance oriented test.
3. Very good correlations exist between wide-width tensile strength, grab breaking load and trapezoid tearing strength. Among these tests, the wide-width tensile test is dominant as a performance oriented test.
4. Excellent linear correlations exist between static puncture strength and wide-width tensile strength (introduced as the average along the machine and cross-machine direction)
5. Mass per unit area could be a very good quantitative indicator of the static puncture and the wide-width tensile strength of nonwoven geotextiles. Caution should be exercised when data from geotextiles with markedly different raw materials and manufacturing processes are combined.
6. The establishment of correlations between the properties of geotextiles per manufactured geotextile series can result in reduced costs for quality control, quality assurance and specification conformance testing.
7. European standard practice which defines the requirements for geotextiles in different application by the wide-width tensile strength and the static puncture strength, is strongly supported by the very good to excellent correlations of these properties to other mechanical properties as well as to mass per unit area.

## 5 ACKNOWLEDGEMENTS

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## 6 REFERENCES

Agosti, A., Cazzuffi, D., Mongiovi, L., 2000: Validation of the comparison between wide-width tensile test and static puncture test on geotextiles, Proceedings of the 2nd European Geosynthetics Conference, Bologna, Italy, Volume 2, pp.855-858

Atmatzidis, D.K., Chrysikos, D.A., 2000: On the burst strength of nonwoven geotextiles, Proceedings of the 2nd European Geosynthetics Conference, Bologna, Italy, Volume 2, pp. 859-863

Atmatzidis, D.K., Chrysicos, D.A., 2002: On the static puncture strength of nonwoven geotextiles, Proceedings of the 7th International Conference on Geosynthetics, Nice, France, Volume 4, pp. 1363-1366

Cazzuffi, D., Venesia, S., Rinaldi, M., Zocca,A., 1986: The mechanical properties of geotextiles: Italian standard and interlaboratory test comparison, Proceedings of the 3rd International Conference on Geotextiles, Vienna, Austria, Volume 3, pp. 695-700

DeBerardino, S., 1994: The role of mullen burst in geotextile specifications, Geotechnical Fabrics Report, Volume 12, Number 4, pp. 41-43

Frobel, R.K., Montalvo, J.R., 1993: A comparison of three commonly specified axisymmetric stress tests for geosynthetics, Proceedings Geosynthetics '93, IFAI, Vancouver, Canada, Volume 2, pp. 561-570

GFR, 2002: Specifier's guide 2003, Geotechnical Fabrics Report, Volume 20, Number 9, pp. 61-97

Kinney, T., 2000: ASTM D35.01 recommends replacing mullen burst test with CBR puncture test for geotextiles, Geotechnical Fabrics Report, Volume 18, Number 3, p. 11

Koerner, R.N., Monteleone, M.J., Schmidt, J.R., Roethe, A.T., 1986: Puncture and impact resistance of geosynthetics, Proceedings of the 3rd International Conference on Geotextiles, Vienna, Austria, Volume 3, pp. 677-682

Koerner,R.M., Daniel,D.E., 1993: Manufacturing and construction quality control and quality assurance of geosynthetics, MQC/MQA and CQC/CQA of Geosynthetics, Industrial Fabrics Association International, St. Paul, USA, pp. 1-14

Montalvo, J.R., Sickler, W., 1993: Comparison of geotextiles- The correlation between test methods and practical performance, Proceedings Geosynthetics '93, IFAI, Vancouver, Canada, Volume 2 pp. 547-559

Moritz, K., Murray, H., 1982: Comparison between different tensile tests and the plunger puncture test (CBR test), Proceedings of the 2nd International Conference on Geotextiles, IFAI, Las Vegas, USA, Volume 3, pp. 757-762

Richards, E.A. and Scott, J.D., 1986: Stress-strain properties of geotextiles, Proceedings of the 3rd International Conference on Geotextiles, Vienna, Austria, Volume 3, pp. 873-878

Sprague, C.J., 1995: Manufacturing quality control and certification of geotextiles, Geosynthetics International, Volume 2, Number 3, pp. 587-601

Wayne, M.H., Christopher, B., 1993: Manufacturing quality assurance and construction quality control of polypropylene geotextiles, MQC/MQA and CQC/CQA of Geosynthetics, Industrial Fabrics Association International, St. Paul, USA, pp. 61-67

Zanzinger, H., 2000: Geosynthetics certification through Europe, Proceedings of the 2nd European Geosynthetics Conference, Bologna, Italy, Volume 2, pp. 875-880