On the burst strength of nonwoven geotextiles

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ABSTRACT: The burst strength of nonwoven geotextiles is determined by small-scale index tests, hydraulic of "Mullen" burst according to ASTM D3786, for product documentation, specification conformance and quality assurance purposes. An experimental investigation was conducted in order to evaluate the possibility of utilizing alternative testing approach, based on the provisions of ASTM Standard D3787, and to correlate the hydraulic burst-strength of nonwoven geotextiles with other physical and mechanical properties. Statistical processing of the available data, yield very good linear correlutions between hydraulic and mechanical burst strength as well as between hydraulic burst, strength, was per unit area and grab breaking load, with correlation coefficients ranging between 0,93 and 0,98.

1 INTRODUCTION

The burst strength of geotextiles is an index property frequently used for the design of separation, drainage and erosion control applications. Whether designing "by specification" or "by function", an allowable value, based on laboratory tests, should be provided by the product manufacturer (Richardson and Koerner, 1992; Koerner, 1994; Holtz, Christopher and Berg, 1997). Accordingly, a large number of burst strength tests is conducted either for quality assurance during the manufacturing process or for specification conformance.

The most common type of test for determining burst strength is the "Mullen" or hydraulic burst test, which is specified by ASTM Standard D3786 (hydraulic bursting strength of knitted goods and nonwoven fabrics-diaphragm bursting strength tester method). This test was originally developed as a quality control test procedure for the textile industry to replicate an elbow going through the sleeve of a garment (DeBerardino, 1994). In this test, an inflatable rubber membrane is used to deform the geotextile out of plane, thereby stressing it in tension until failure occurs. The burst strength, reported in pascals, depends on the tensile strength of the geotextile in all directions and is controlled by the minimum tensile strength value. However, the result obtained by a burst test is the normal stress against the geotextile and not the stress in the specimen.

Laboratory equipment for conducting hydraulic burst tests (Mullen testers) is available from a limited number of manufacturers. The available testers may be classified as low pressure (up to 1400 kPa) and high pressure (from 1400 kPa to 10000 kPa) machines. However, available information on the burst strength of nonwoven geotextiles indicates that it ranges from as low as 500 kPa to over 6500 kPa. (Holtz, Christopher and Berg, 1997; Geotechnical Fabrics Report, 1998). Accordingly, a testing laboratory should be equipped with both low pressure and high pressure machines is order to be able to test the full range of nonwoven geotextiles.

An alternative testing method is offered by ASTM Standard D3787 (bursting strength of knitted goods-constant rate of traverse ball burst test). This test method requires the use of a constant-rate-of-traverse loading frame which is available in most, if not all, testing laboratories. The specimen is held in a ring clamp mechanism with an internal diameter of 44.45 mm and is loaded by an attachment having a polished steel ball with a diameter of 25.40 mm. Such ring clamp and steel ball attachments are easy and economical to construct. The results from such a test are reported in newtons and there is no obvious method for correlating them to results obtained by a "Mullen" tester.

Available information on nonwoven geotextile properties, presented as minimum average roll values (Geotechnical Fabrics Report, 1998), can be used to obtain a first order approximation of correlations between the hydraulic burst strength and other physical and/or mechanical properties of nonwoven geotextiles. Toward this end, the grab breaking load and the mass per unit area were selected since they are two properties most frequently reported by the manufacturers. Presented in Figure 1 are hydraulic burst strength and grab breaking load data for 164 nonwoven geotextiles, indicating a very good first order relationship with a correlation coefficient R^2=0.912. The burst strength and mass per unit area data for 72 nonwoven geotextiles, presented in Figure 2, show an even better correlation with a coefficient R^2=0.958.

The foregoing observations on the need for burst testing, the availability of testing equipment and possible property correlations, provided the impetus for the experimental investigation reported herein. Following a brief description of the equipment used to conduct burst tests on 53 different nonwoven geotextiles, the experimental results are presented and utilized to produce correlations between hydraulic and ball burst strength values as well as between hydraulic burst strength and other properties (grab breaking load and mass per unit area) of the geotextiles.

2 EXPERIMENTAL PROCEDURES

For the purposes of the experimental investigation reported herein, samples of nonwoven geotextiles were obtained from six different manufacturers. The size of the samples obtained ranged from 2m^2 to 6m^2. The number of different nonwoven geotextiles provided by each manufacturer ranged from four to fourteen, yielding a total of fiftythree samples for testing. The group of geotextiles tested, included needle-punched and heat-bonded products made of continuous or staple filaments as well as posttreated products (thermal surface treatment on one or both sides). In order to avoid the use of commercial names, a generic notation is used to identify products and manufacturers: symbols M1 and M2 indicate heat-bonded products, M3 indicates needle-punched including a number of posttreated products and M4, M5, M6 indicate needle-punched products. In subsequent figures, numbers in parenthesis next to an identification number, i.e. M1 (12), indicate the number of samples in that particular group of geotextiles.

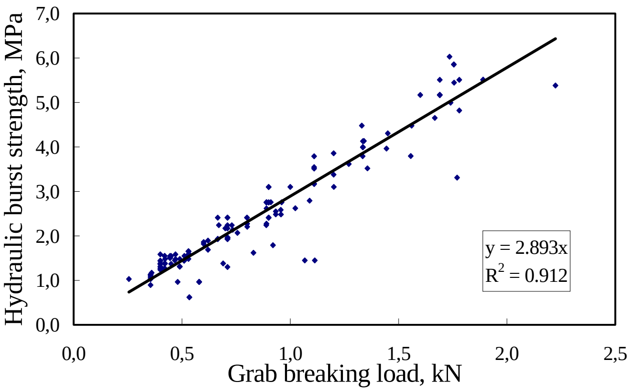

Figure 1. Correlation between hydraulic burst strength and grab breaking load from manufacturers’ data.

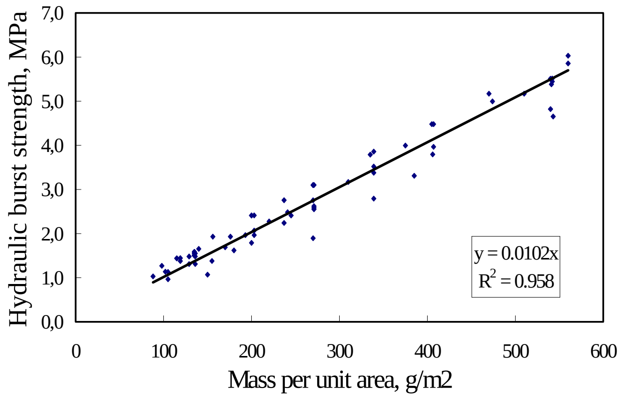

Figure 2. Correlation between hydraulic burst strength and mass per unit area from manufacturers' data.

The mass per unit area and grab breaking load values provided by the manufacturers were verified in the laboratory by conducting tests according to ASTM Standards D5261 and D4632, respectively. For the few cases where this information was not available, it was produced experimentally. For the fifty-three geotextiles tested, the mass per unit area ranged from 68 g/m^2 to 650 g/m^2 and the grab breaking load ranged from 280 N to 3465 N. Burst strength values were obtained according to ASTM D3786 (hydraulic burst strength) and ASTM D3787 (ball burst strength). All tests were conducted under standard conditions for testing geotextiles (relative humidity 65±5%, temperature 21±2^{o}C) and using the number of specimens specified by each standard.

Figure 3. Hydraulic burst strength tester.

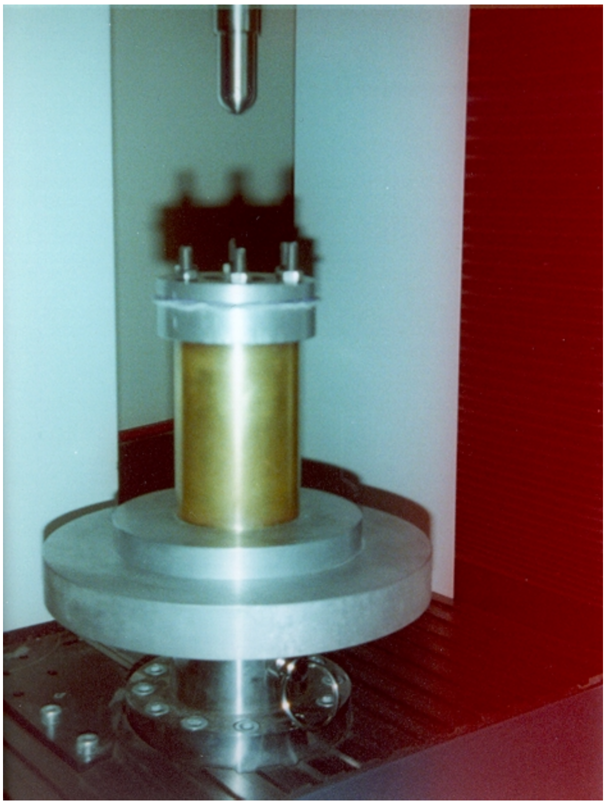

Figure 4. Attachments for ball burst testing.

The equipment used to conduct hydraulic bursting strength tests is shown in Figure 3. This testing machine was constructed in-house and meets all the specifications set by ASTM Standard D3786. The diaphragm is made of synthetic rubber, has a thickness of 2.0 mm and a "tare pressure" of 15 kPa. Hydraulic pressure to the underside of the diaphragm is applied through a fluid displacement pump with controlled variable rate. The fluid used is hydraulic oil type HK46. Maximum pressure is recorded by a manometer as well as electronically for improved accuracy. A pressure of up to 12 MPa can be applied.

A computer controlled 100 kN constant-rate-of-traverse loading frame was used to conduct ball burst tests according to ASTM Standard D3787. Shown in Figure 4 are the specimen ring clamp attachment and the steel rod with semispherical end which were constructed in-house for the purposes of this experimental investigation.

3 RESULTS AND DISCUSSION

The results obtained from hydraulic burst testing (ASTM D3786) and ball burst testing (ASTM D3787) are presented in Figure 5. It can be observed that, as a first order approximation, a linear relationship exists between the hydraulic and the ball burst strength for each group of nonwoven geotextiles tested. No apparent distinction can be made in terms of manufacturing process. The linear correlation appears to be very good in terms of the correlation coefficient, R^2, which attains values ranging from 0,938 to 0,988. When the complete set of data is fitted by a linear function, the correlation coefficient is R^2=0,959 and the ratio of hydraulic burst strength to ball burst strength is equal to 1.62. Using this multiplication factor, the hydraulic burst strength can be computed in terms of the ball burst strength with an error ranging from -25% to +17%. However, this error is

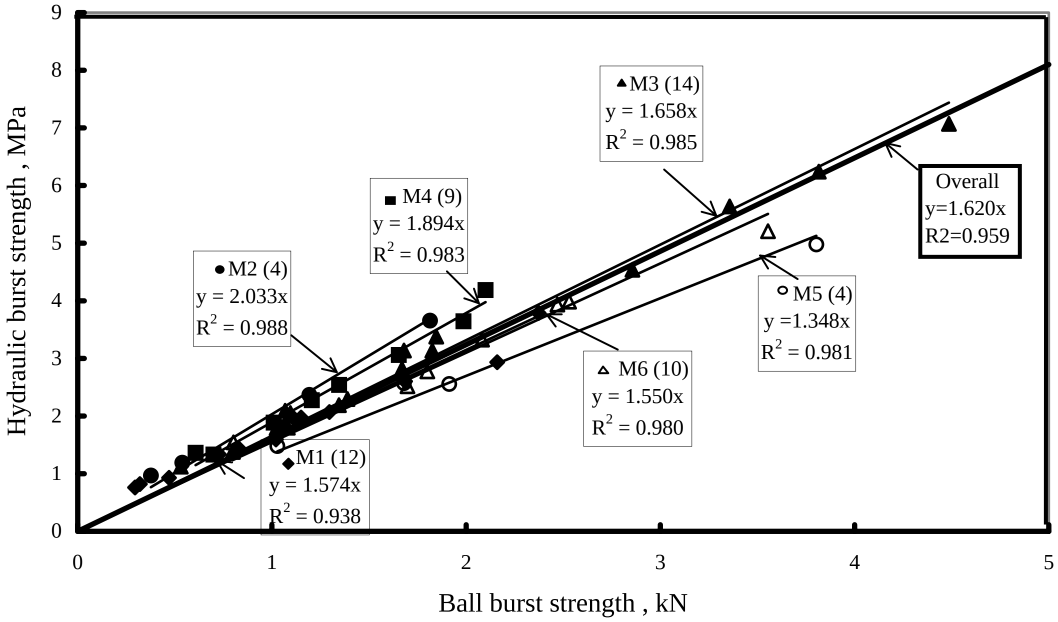

Figure 5. Experimental correlation between hydraulic and ball burst strength.

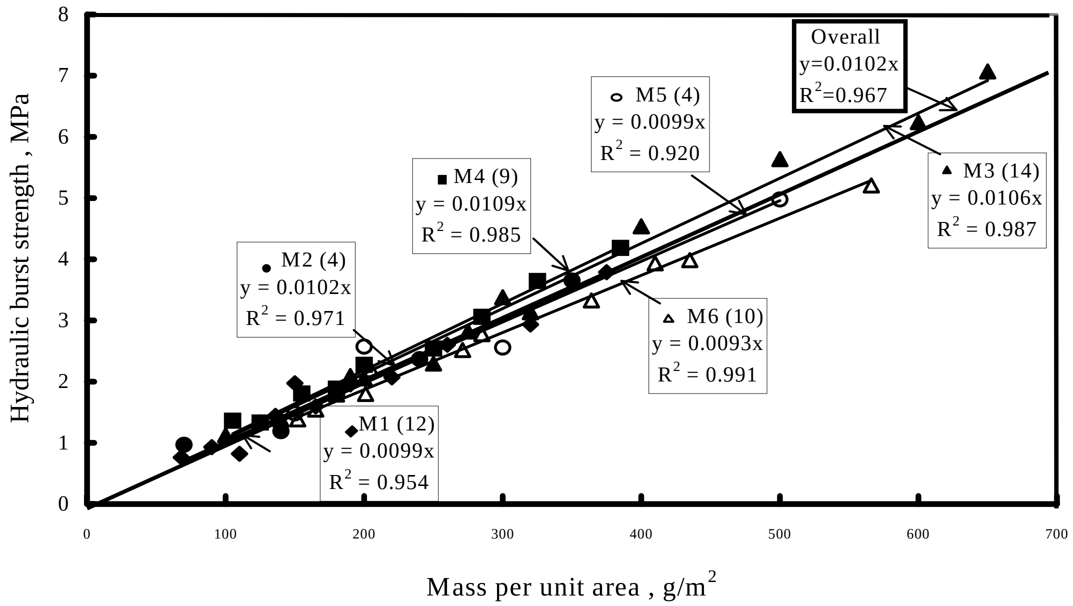

Figure 6. Experimental correlation between hydraulic burst strength and mass per unit area.

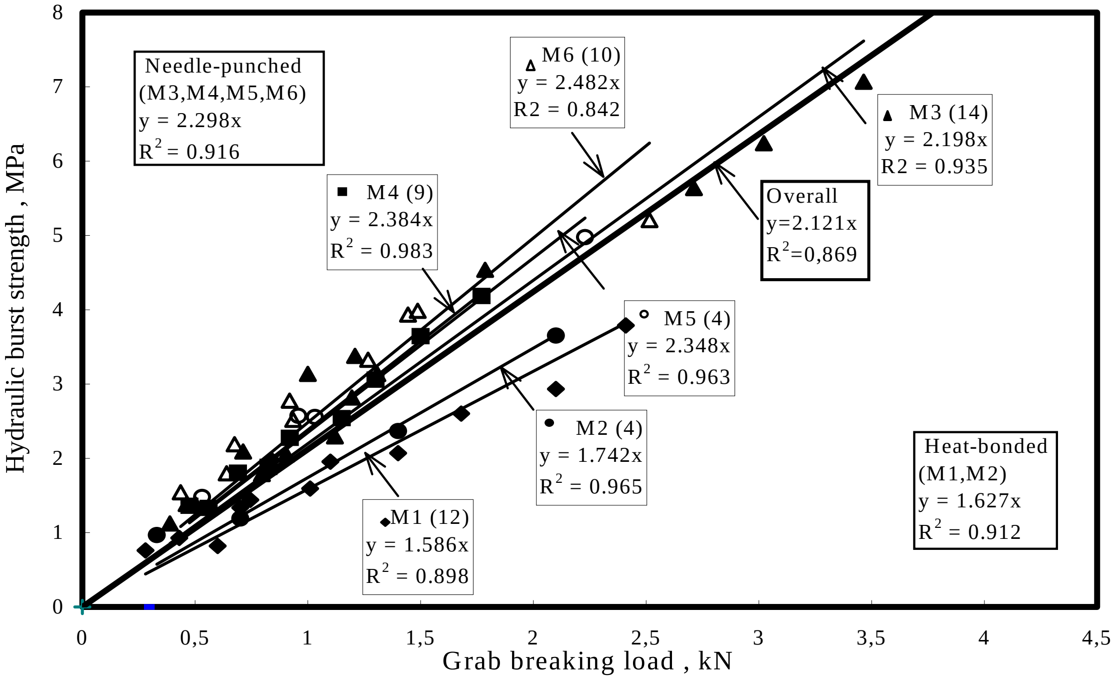

Figure 7. Experimental correlation between hydraulic burst strength and grab breaking load.

reduced to less than ±4% for 67% of the samples tested which represent groups M1,M3 and M4. These observations indicate that the ball burst test (ASTM D3787) is a viable alternative to the hydraulic burst test, considering that both tests should be classified as index value tests. Further testing with different geotextiles, in terms of manufacturing process and raw materials, may lead to a more elaborate correlation.

The first order approximation of a relationship between hydraulic burst strength and mass per unit area, as shown in Figure 6, is impressive. The correlation coefficients, R^2, obtained per group of geotextiles tested range from 0,920 to 0,991. When the complete set of data is fitted by a linear function, the correlation coefficient is R^2=0,967 and the hydraulic burst strength (in kPa) can be estimated by multiplying the mass per unit area (in g/m^2) by 10.2 with an error ranging from -9% to +7%. This error is reduced to less than ±4% for 64% of the samples tested which represent groups M1, M2, M3 and M5. This correlation is in excellent agreement with the correlation shown in Figure 2 which was obtained by using available published data for a larger number of nonwoven geotextiles. The overlap between the data shown in Figure 2 and the experimental data presented in Figure 6, in terms of the same products included in both sets, is approximately 10%. These observations strongly indicate that the hydraulic burst strength can be estimated with confidence when only the mass per unit area of nonwoven geotextiles is known, regardless of manufacturing process or raw materials.

An interesting behavior is observed for the relationship between hydraulic burst strength and grab breaking load. As shown in Figure 7, the data obtained can be grouped according to manufacturing process. Although a reasonable linear relationship, as a first order approximation, exists for each group of geotextiles tested, heat-bonded products (groups M1 and M2) exhibit a distinctly different correlation than needle-punched products (groups M3, M4, M5 and M6). Accordingly, the ratio between hydraulic burst strength (in MPa) and grab breaking load (in kN) is 1.63 and 2.30 for heat-bonded and needle-punched products, respectively. This difference in behavior indicates that needle-punched products, with the same grab breaking load as heat-bonded products, may offer an advantage since they yield higher burst strength values. However, this advantage is at least partly negated since heat-bonded products having the same mass per unit area as needle-punched products, yield higher grab breaking load values. When the complete set of data is fitted by a linear function, the correlation coefficient is R^2=0,869 and the ratio between hydraulic burst strength (in MPa) and grab breaking load (in kN) is 2.12. Use of this relationship allowes the estimation of the hydraulic burst strength with an error ranging between -26% and +17%. However, when different correlations are applied for heat-bonded and needle-punched products, this error is reduced to an average of ±5%.

4 CONCLUSIONS

Based on the results and observations made during the limited experimental investigation reported herein, the following conclusions may be advanced:

1. The ball burst strength test, conducted according to ASTM D3787, is a viable alternative to the hydraulic burst strength test (ASTM D3786) for nonwoven geotextiles. An acceptable correlation exists between results obtained from these two tests.
2. The mass per unit area of nonwoven geotextiles is an excellent quantitative indicator of the hydraulic burst strength. As a first order approximation it can be stated that the hydraulic burst strength, expressed in kPa, is ten times the mass per unit area of the geotextile, expressed in g/m^2.
3. The correlation between hydraulic burst strength and grab breaking load of nonwoven geotextiles is strongly dependent on manufacturing process. Very good but different linear correlations exist for heat-bonded and needle-punched products.

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