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A Wide Strip Tensile Test of Geotextiles

Essai de traction des géotextiles sur eprouvette large

A strip tensile test program studied the effects of test variables on laboratory measurement of tensile loads and strain. Considered were specimen size and aspect ratio, rate of strain, test methods, and sample variability. The specimen size is not very significant for ultimate load measurements. Moduli of geotextiles, however, varied significantly with specimen size and aspect ratio for nonwoven fabrics. Effects of specimen width were insignificant for woven geotextiles.

On the basis of these data, a wide strip tensile test with specimen 200 mm (8 inches) wide and 100 mm (4 inches) gauge length is recommended for routine measurement of tensile properties. At this specimen size, the tensile load-strain plots of the six geotextiles tested were not significantly different from those obtained from plane-strain tests. Strain rates of 1-1/4 to 12 percent per minute did not show significant difference in the results and 10 percent is recommended. In view of the sample variability of geotextiles, a precision of ± 10% at 95% probability is recommended to provide acceptable accuracy.

L'influence des variables d'essais sur les mesures en laboratoire des efforts de tension et des propriétés à la déformation a ete etudiee. Les paramètres suivants ont ete considérés: dimension de l'éprouvette et rapport longueur sur largeur, taux de déformation, méthode employée ainsi que variabilité de l'échantillon. La taille de l'éprouvette est negligeable dans le cas des mesures à la charge de rupture. Par contre, dans le cas de géotextiles non tissés, les modules des géotextiles ont changé d'une manière significative avec la taille de l'éprouvette et le rapport longueur sur largeur. L'influence de la largeur de l'éprouvette a été negligeable pour les géotextiles tissés. Suivant ces résultats, on recommende une éprouvette large de 200 mm et longue de 100 mm. Avec ces dimensions, pour les six géotextiles utilisés, les courbes de l'effort de tension en fonction de la déformation n'apparaissent pas très différentes des courbes obtenues dans le cas d'experience en deux dimensions. Des Taux de déformation de 1-1/4 a 12% par minute n'ont pas montré de difference significative dans les résultats; et on recommende d'utiliser 10%. Une précision de ± 10% a 95% de probabilité est recommendée.

INTRODUCTION

The satisfactory field performances of geotextiles in civil engineering applications such as earth reinforcement depend to a large extent on the tensile loads and strain properties of the geotextiles. It is agreed unequivocally that the standard laboratory tensile tests used for textile fabrics do not represent the field conditions normally imposed on geotextiles. In many applications the geotextiles are stressed in plane-strain conditions. Therefore, the standard tensile tests used for textile fabrics are generally considered as "inappropriate and misleading" for geotextiles (1). Various new test methods including a hydraulic trough test with zero transverse strain (1), biaxial tensile tests (2), cylindrical sleeve tests (3), and others have been devised and suggested for laboratory evaluation of geotextiles. These test methods have the capability of duplicating the in-situ load and strain conditions of geotextiles; however, all are believed to be too complex for routine laboratory use.

This paper presents the results of a laboratory investigation to develop a wide strip tensile test appropriate for routine laboratory measurement of tensile stress and strain properties of geotextiles (4). A total of 383 tensile test runs were performed on six typical geotextiles to include test variables of specimen size, width to length ratio, rate of strain, plane-strain and uniaxial loading, and sample variability. The plane-strain condition was simulated by installing light wooden brackets set with pins to restrain the test specimen from contracting in the transverse direction (5).

TEST EQUIPMENTS AND PROCEDURE

The equipments used in this experimental work consisted of standard tensile testing machines, automatic load and elongation recorder and special wide jaws. The special jaws consisted of 229 mm (9 inches) wide by 57 mm (2-1/4 inches) high serrated faces. Specimens were trimmed to the final dimensions to a tolerance of ± 3 mm (1/8 inch). Each specimen was weighed to evaluate sample variabilities. The specimens were installed in the special jaws, mounted in the tensile test machine, and loaded at a constant rate of strain at laboratory temperature.

SAMPLE SELECTION

The type of geotextile construction has a great influence on the tensile load and strain characteristics. Therefore, several geotextile constructions were selected for testing as shown in Table 1.

Table 1. Geotextiles Investigated

Number	Fiber-Polymer	Construction
NW-1	Continuous Polyester	Nonwoven Resin bonded
NW-3	Continuous Polypropylene	Nonwoven Heat bonded
NW-5	Continuous Polypropylene	Nonwoven Needlepunched
NW-6	Staple Polypropylene	Nonwoven Needlepunched
W-4	Monofilament Polypropylene	Woven
C-1	Slit Film Polypropylene	Woven-needled nap

EXPERIMENTAL RESULTS

The testing program is listed in Table 2. Test variables were specimen size and aspect ratio (defined as specimen width to gauge length), rate of strain, test method, and sample variability.

Table 2. Strip Tensile Test Series

Series Number	Test Method	Width x Gauge Length (mm)	Strain Rate (% per minute)	Fabrics Tested	Specimens Each Test
1	Strip	200 x 25 MD	5	6	5
		200 x 50 MD	5	6	5
		200 x 100 MD	5	6	5
		200 x 200 MD	5	6	5
2	Strip	25 x 100 MD	5	6	5
		50 x 100 MD	5	6	5
		100 x 100 MD	5	6	5
		150 x 100 MD	5	6	5
3	Strip	200 x 100 MD	1-1/4	6	3+
		200 x 100 MD	12-1/2	6	5
4	Plane-Strain	200 x 100 MD	5	6	5

Notes: MD = Machine Direction

+Since the strain rate was very slow, only three specimens were tested for each fabric.

The laboratory room temperature and humidity were 68°F to 82°F and 20% to 58%.

Effect of Specimen Size and Aspect Ratio

Test Series 1 and 2 were performed to investigate the effect of aspect ratio on the tensile test results. In Test Series 1, specimen gauge length, defined as the initial length of fabric between the test jaws, was varied from 25 mm (1 inch) to 200 mm (8 inches) and the specimen width was constant at 200 mm (8 inches). In Test Series 2, the specimen width was varied from 25 mm (1 inch) to 200 mm (8 inches) and the specimen gauge length was invariant at 100 mm (4 inches). The results of the Series 1 and 2 tests are presented in Figures 1 to 10.

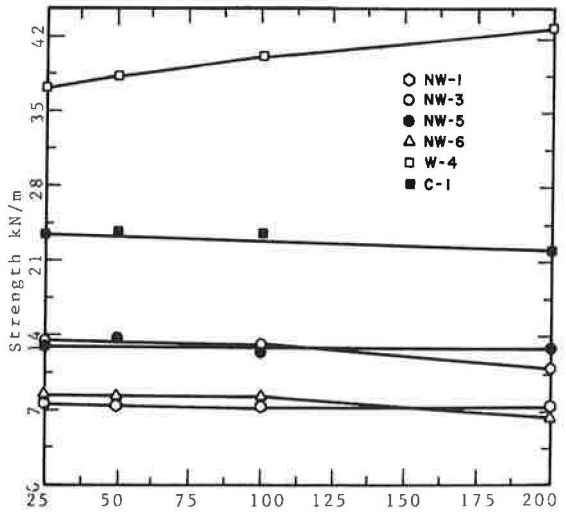

FIGURE 1: Strength vs. Gauge Length
Specimen Width 200 mm (8 inches)

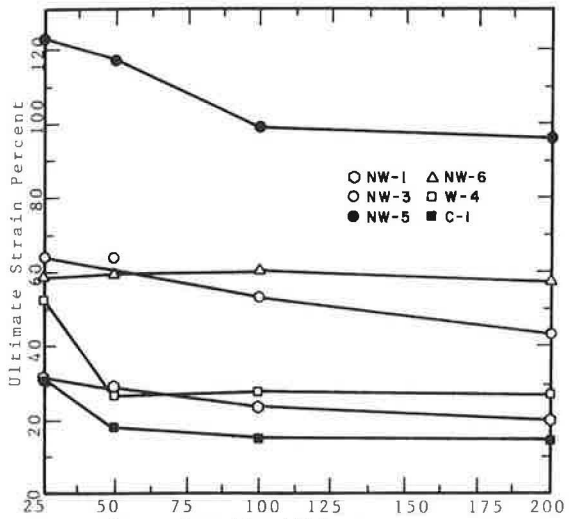

FIGURE 2: Ultimate Strain vs. Gauge length
Specimen Width 200 mm (8 inches)

Figures 1 and 2 show the ultimate loads (strength) and strains plotted as functions of specimen gauge lengths with specimen width constant at 200 mm (8 inches). The strength remained practically constant for all geotextiles, except for W-4 which showed about 14% increase with increase in gauge length. The ultimate strains generally decreased with increase in length. This decrease was most pronounced for very short specimens and for woven fabrics.

Figures 3 and 4 present loads at 10% strain and strains at 40% strength as functions of gauge lengths. The loads on the woven geotextiles increased by about 50% with increase in the gauge length up to 50 mm (2 inches) and then remained practically constant with further increases.

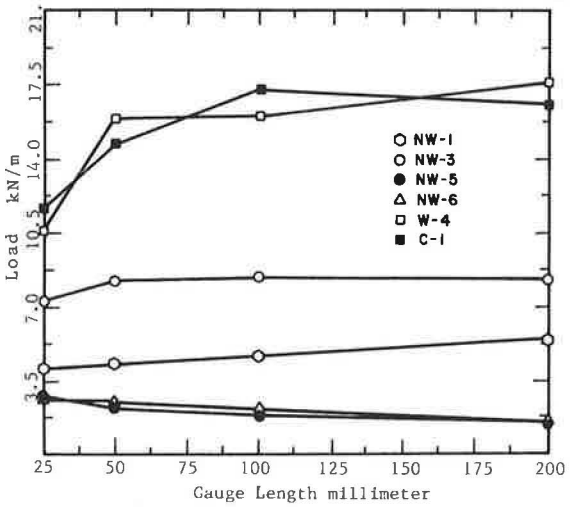

FIGURE .3: Load vs. Gauge Length.
Specimen width 200 mm (8 inches)
Strain = 10 percent

The loads for the nonwoven geotextiles showed less effects. The strains decreased with increase in specimen gauge length to 100 mm (4 inches) for the bonded nonwoven

and woven geotextiles, however, for the needlepunched nonwovens, they increased.

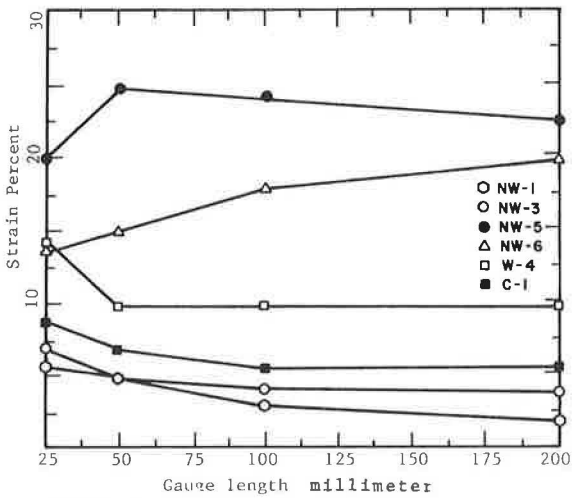

FIGURE .4: Strain vs. Gauge Length
Specimen width 200 mm (8 inches)
Load = 40% Strength

Figure 5 shows that ultimate loads (strengths) of geotextiles remain almost constant with increase in specimen width for the 100 mm (4 inches) wide specimens. However, Figure 6 shows that ultimate strain may be significantly affected depending on geotextile structure.

Figures 7 and 8 show plots of stresses at 10% strain and strains at 40% strength respectively as functions of

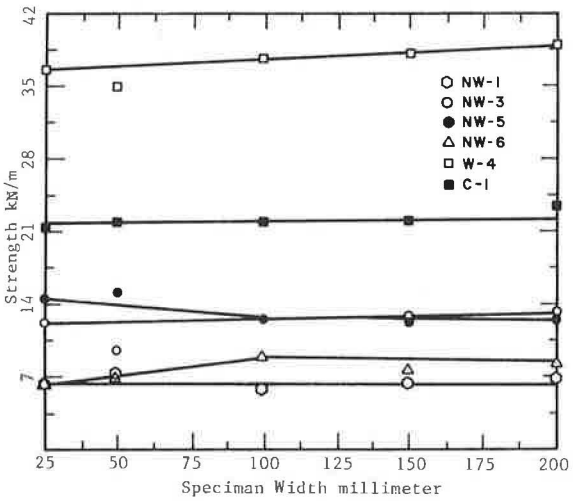

FIGURE .5: Strength vs. Specimen Width.
Gauge length 100 mm (4 inches)

specimen width. The stresses of the nonwovens increased by 5% to 100% with increase in specimen width up to 100 mm (4 inches). For wider specimens, the stresses remained practically constant. For the wovens, the initial stresses remained practically constant at all specimen widths. The strains of the needlepunched nonwovens de-

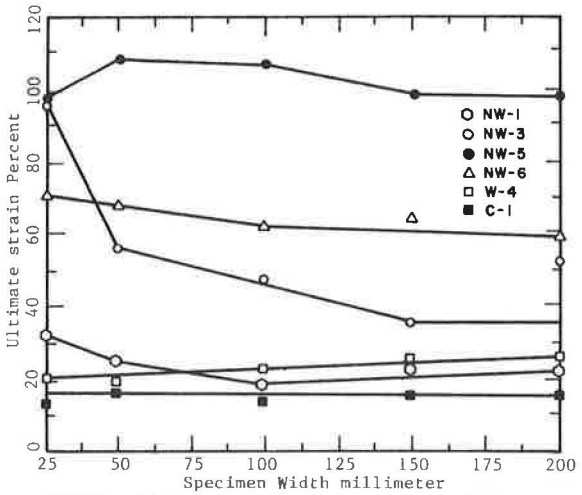

FIGURE .6: Ultimate strain vs. Specimen Width.
Gauge length 100 mm (4 inches)

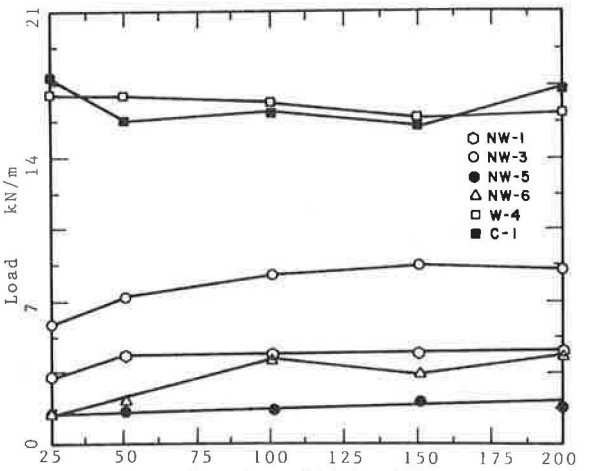

FIGURE 7: Load vs. Specimen Width
Strain = 10%, Gauge length =
200 mm (8 inches)

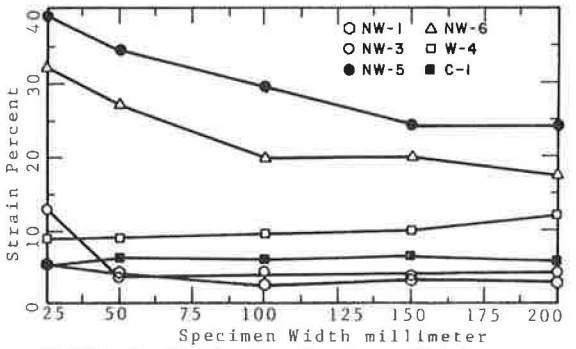

FIGURE 8: Strain vs. Specimen Width
Load = 40% Strength, Gauge
length = 200 mm (8 inches)

creased with increases in specimen widths to 100 mm (4 inches). For the wovens and bonded nonwovens, however, the specimen width did not appear to have a significant effect.

The results of Series 1 and 2 tests are combined in Figures 9 and 10. The trends are similar for all geotextiles; however, for woven geotextiles, the loads and strains are most influenced by aspect ratios greater than 4.0, whereas, the nonwoven fabrics are most influenced by aspect ratios less than 2.0.

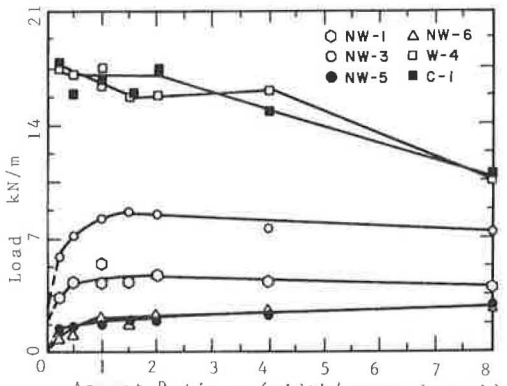

FIGURE 9: Load vs. Aspect Ratio
Strain = 10%

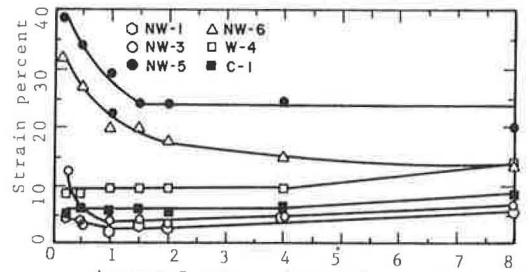

FIGURE 10: Strain vs. Aspect Ratio
Load = 40% strength

Effect of Strain Rate

The results of Series 3 tests in which strain rates from 1-1/4 to 12-1/2 percent per minute were applied to specimens of size 200 mm (8 inches) wide and 100 mm (4 inches) gauge length are presented in Table 3. The ultimate tensile loads do not show any consistent trend with variation in strain rates. Further, plots of the test results showed that strain rates from 1-1/4 to 12-1/2 percent per minute for practical purposes show the same tensile load and strain behavior. These plots are not included due to space limitations.

Effect of Test Method (Plane-Strain Versus Strip Tensile Tests)

For Test Series 4, plane-strain condition was simulated on specimens of size 200 mm (8 inches) wide and 100 mm (4 inches) long by installing light wooden brackets set with pins similar to the ones devised by Sissons (5) to restrain the specimens from lateral contraction (necking)

Table 3. Ultimate Load and Strain at Different Strain Rates

	12-1/2% per minute		5% per minute		1-1/4% per minute	
Fabric	Load kN/m	Strain %	Load kN/m	Strain %	Load kN/m	Strain %
NW-1	8.05	23	7.70	22	7.88	23
NW-3	13.65	49	13.30	53	13.30	62
NW-5	0.032*	97	0.030*	91	0.036*	115
NW-6	8.23	56	8.23	60	8.58	65
W-4	36.93	22	40.25	28	38.85	29
C-1	23.10	14	23.63	15	22.05	17

*Normalized to gm/m^2 1 lbs/inch = 0.175 kN/m

Figures 11 to 13 show plots of the tensile load-strain curves for the geotextiles NW-1, NW-3, and NW-6. It is apparent from these curves that the two test methods (strip tensile and Sissons plane-strain) give almost identical results for the specimen size 200 mm (8 inches) wide and 100 mm (4 inches) long. This was also true for the other geotextiles tested.

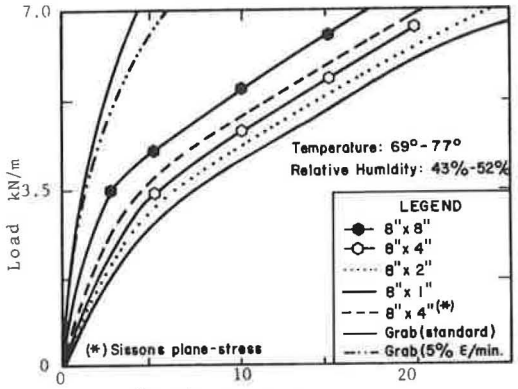

FIGURE 11: Load -Strain Relationships of NW-1 Geotextile for Different Specimen Sizes and Test Methods.

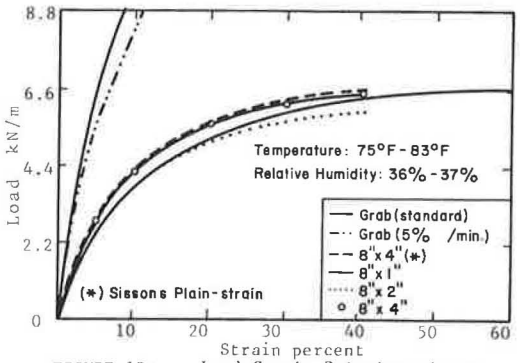

FIGURE 12: Load-Strain Relationship of NW-3 Geotextile for Different Specimen Sizes and Test Methods.

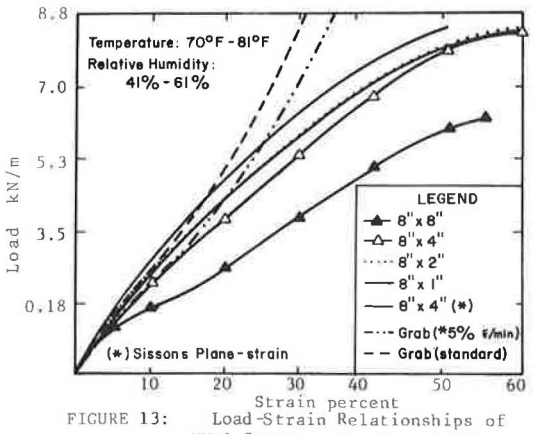

FIGURE 13: Load-Strain Relationships of NW-6 Geotextile for Different Specimen Sizes and Test Methods.

Effect of Sample Variability

A minimum of five specimens were tested for each test variable. All the results presented in previous sections are averages of five specimens. Table 4 presents the maximum coefficients of variation calculated from Series 1 to 5 test results and the minimum number of specimens required to obtain three different levels of precisions on the basis of Student's t-distribution (6).

Table 4. Test Specimens Required for Different Precisions and Probability Levels

Fabric	Max. Coeff. of Variation	± 5% Precision 95% Probability	± 5% Precision 90% Probability	± 10% Precision 95% Probability*
NW-1	.20	64	45	16
NW-3	.12	22	16	6
NW-5	.13	28	20	7
NW-6	.13	27	20	7
W-4	.07	8	5	2
C-1	.09	12	8	3

*Using Student's t-distribution (6), $n = 0.038\ v^2$ for ± 10% precision at 95% probability level; where n = number of test repetitions, and v = coefficient of variation.

DISCUSSION OF RESULTS

Results in Figures 1 and 5 show the effects of specimen width and gauge length on tensile strength are not significant compared to the effects on ultimate strains illustrated in Figures 2 and 6.

Both the loads at 10% strain (Figures 3 and 7) and strains at 40% of strength (Figures 4 and 8) are influenced by the specimen width and gauge length. The amount of variation differs from one geotextile type to another. For woven geotextiles, gauge lengths less than 50 mm (2 inches) show large variations in these loads and strains. Specimen width, however, did not appear to have a significant influence for the wovens. For nonwoven geotextiles, gauge lengths less than 100 mm (4 inches) show large variations in loads and strains. From the plots of the combined effects of both specimen widths and gauge lengths in Figures 9 and 10, aspect ratios less than 4 for wovens and greater than 2 for nonwovens show insignificant variation in both loads and strains. Apparently a satisfactory specimen size for strip tensile tests of both woven and nonwoven geotextiles corresponds to an aspect ratio equal to 2 with a specimen width equal to at least 200 mm (8 inches). Tests performed at this specimen size approximate the plane-strain condition as simulated by the Sissons method (5) as shown in Figures 11, 12, and 13.

The strain rates of 0.5% to 1% per minute normally used in geotechnical laboratory tests are too slow to be economical for geotextiles because of their much higher strains at failure. For example fabric NW-5 would require at least two hours for each specimen at a strain rate of 1% per minute. Series 3 test results show tensile load-strain curves are not significantly different at strain rates of 1-1/4%, 5% and 12-1/2%. On the basis of this observation, a test rate of 10% per minute appears to be reasonable for routine laboratory tests.

The coefficient of variation varied from one geotextile type to another as shown in Table 4 by as much as 30%. Initial laboratory tests should include at least five specimens. Then on the basis of the coefficient variation calculated from these results, the number of specimens required for a desired level of probability can be calculated by using the Student's t-distribution (6). The number of test specimens required as shown in Table 4 to obtain results within ± 10% precision at 95% probability level is not excessively large and this provides reasonable accuracy for routine tensile tests of geotextiles.

CONCLUSIONS AND RECOMMENDATIONS

1. The ultimate strengths of geotextiles measured in strip tensile tests are not significantly affected by specimen size; however, the failure strains of the laboratory specimens are affected significantly by specimen width and gauge length.
2. Load-strain relationships measured for geotextiles may vary considerably with specimen width and gauge length. Woven geotextiles are most influenced by aspect ratios greater than 4.0 and specimen gauge lengths of less than 50 mm (2 inches). Nonwoven geotextiles are most influenced by aspect ratios less than 2.0 and specimen widths less than 100 mm (4 inches).
3. A wide strip tensile test utilizing specimens 200 mm (8 inches) wide and 100 mm (4 inches) gauge length is recommended for routine laboratory testing. At this specimen size, plane-strain loading conditions on geotextiles can be approximated without use of a restraining device to limit lateral contraction of specimens during strip tensile tests.
4. The laboratory measurements of tensile properties are not significantly different at strain rates 1-1/4 to 12-1/2 percent per minute. A strain rate of 10% per minute is recommended for routine strip tensile tests.
5. A precision within ± 10% at 95% probability is recommended for routine laboratory tensile testing by the wide strip tensile test.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support of the research reported in this paper by the United States Federal Highway Administration.

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