Van DINE, D. and RAYMOND, G.
Queen's University, Kingston, Canada
WILLIAMS, S. E.
EBA Engineering Consultants Ltd., Edmonton, Canada

An Evaluation of Abrasion Tests for Geotextiles

Une évaluation de tests d'abrasion de géotextiles

Resistance to impact and wear abrasion are important properties of geotextiles used in railroad bed construction. A program was designed to compare the standard textile abrasion test (ASTM D1175) with two new abrasion tests designed to simulate impact and wear abrasion of geotextiles in railbeds. Eleven different geotextiles were tested. A scanning electron microscope was used to assess the abrasion processes and severity caused by the three tests. The ASTM D1175 test was found not to simulate abrasion of geotextiles in the railbed. This test did not perform well for non-woven, non-resin dipped fabrics. The Geotextile - Ballast Impact Abrasion Test and the Geotextile - Aggregate Repeated Loading Test did simulate railbed abrasion and performed well on both woven and non-woven geotextiles. In the former test, non-woven geotextiles were more resistant than woven fabrics. In the latter test, woven and non-woven geotextiles abraded approximately the same amount, albeit by different processes. The thicker and heavier fabrics were more abrasion resistant.

La résistance aux impacts et à l'abrasion sont deux propriétés importantes des géotextiles utilisés dans les ballastes ferroviaires. Des essais ont e'té entrepris pour comparer le test ordinaire d'abrasion (ASTM D1175) à deux nouveaux tests d'abrasion permettant la simulation d'impacts et d'abrasion de géotextiles dans les ballastes ferroviaires. Onze géotextiles différents ont e'té soumis aux tests. Un examen, au microscope électronique à balayage, du degré d'abrasion causé par chacun des tests révèle que le test ASTM D1175 ne reproduit pas les conditions d'abrasion dans les ballastes ferroviaires. Ce test n'est pas satisfaisant pour les textiles non tissés et non enduits de résine. Le test d'abrasion due aux impacts et le test de charge répétée reproduisent les conditions d'abrasion dans un ballaste, et donnent de bons résultats sur les géotextiles tissés et non tissés. Le premier test re'vèle que les géotextiles non tissés sont plus résistants que les géotextiles tissés. Dans le second test, les géotextiles tissés et non tissés souffrent d'abrasions égales, mais issues de processus différents. Les textiles épais et lourds résistent mieux à l'abrasion.

INTRODUCTION

Two properties of a geotextile, which are very important to its successful application, are resistance to impact abrasion and resistance to wear abrasion. Nowhere are these properties as critical as when the geotextile is used in the construction or rehabilitation of a railroad bed. During construction or rehabilitation, crushed rock (ballast) is literally dropped onto the geotextile. During normal operation of the railroad, repetitive wheel loads impart a rubbing motion between the ballast and the geotextile and, between the geotextile and the subballast below the geotextile. Excessive abrasion caused by either impact or wear reduces the filter, separator and drainage capabilities of the geotextile. This condition can jeopardize the integrity of the entire railroad structure.

In testing the abrasion resistance of geotextiles it is important to simulate the actual type of abrasion. It was felt that the "Standard Methods of Test for Abrasion Resistance of Textile Fabrics" (ASTM D1175) may not simulate the in-field impact or wear abrasion that geotextiles might undergo in the railbed situation. Therefore, a study program was designed to evaluate a test procedure of ASTM D1175 against two abrasion tests specifically developed to simulate impact and wear abrasion in railbed construction and rehabilitation.

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TESTING PROGRAM

The three abrasion tests used to test the geotextiles, were:

(i) the Rotary Platform, Double Head Procedure of ASTM Test Method D1175: Standard Methods of Test for Abrasion Resistance of Textile Fabric (ASTM, 1971) (the Rotary Abrasion Test);
(ii) the Geotextile-Ballast Impact Abrasion Test (the Ballast Impact Test); and
(iii) the Geotextile-Aggregate Repeated Loading Abrasion Test (The Repeated Loading Test).

The Rotary Platform, Double Head Procedure of ASTM D1175 is the standard method to evaluate the wear abrasion resistance of any textile subject to "rotary rubbing action under controlled conditions of pressure and abrasion action" (ASTM, 1971). Figure 1 shows the standard rotary abrasion tester during an actual test. For this test program two rubber based CS-17 Calibrase abrasive wheels, and a load of 1000 gms were used to abrade the geotextile samples for 10, 100, and 1000 cycles. The test is fully described in the reference and therefore is not described further.

A Geotextile Ballast Impact Abrasion Test was developed to simulate the impact abrasion caused by railway ballast placement on a geotextile. The apparatus for this test is shown in Figure 2. A graded material, passing the 38 mm sieve and retained on the 19 mm sieve, and representing AREA ballast grading No. 4 (American Railway Engineering Association, 1981) was placed and compacted in a wooden container 250 mm square by 75 mm high. A sample of the geotextile to be tested, large enough to cover the surface of the wooden container, was clamped to the sides of the container. An aluminum tube, 150 mm in diameter and 1 metre in length, was placed vertically over the container and geotextile. Approximately 5.0 kg of AREA ballast grading No. 4 was placed within another shorter aluminum tube above a removable trap door which was located exactly 1 metre above the geotextile. The trap door was quickly removed to allow the ballast to impact onto the geotextile. Samples were tested at 5 drops and 10 drops of ballast.

A Geotextile-Aggregate Repeated Loading Abrasion Test was also developed. This test was designed to simulate the wear abrasion caused by aggregate (ballast or subballast) on a geotextile used as a separation layer in the railbed. The apparatus for this test is shown in Figure 3. An aluminum cylinder, 250 mm in diameter, 300 mm high and closed at one end, was used. Standard Ottawa Sand, passing a 0.84 mm sieve and retained on a 0.59 mm sieve, was used to fill the bottom 50 mm of the cylinder.

Two tests were conducted simultaneously. One disc of the geotextile to be tested was placed on top of the sand and covered with 65 mm of ballast. This represented wear abrasion of the geotextile placed under ballast and sitting on a sand subballast or subgrade. A second disc of the same geotextile was placed on the previously mentioned lift of ballast and covered by a second 65 mm lift of ballast. This simulated the wear abrasion of the geotextile between two ballast lifts, or between ballast and subballast. The ballast used for both lifts was AREA grading No. 4. A repeated loading, rigid footing device, 100 mm in diameter, was clamped in place with a size 12 diaphragm air cylinder (Bellofram Products Company). The footing was then repeatedly loaded to 290 kPa and then fully unloaded. Three series of tests were performed at 1000, 10,000 and 100,000 cycles.

Eleven geotextiles were tested in this study. The selection of these samples was based upon the method of manufacture (woven vs. non-woven), type of polymer, filament characteristic, mass and thickness. It was attempted to study as broad a cross section of geotextiles types as possible. A complete description of the geotextiles tested is given in Table 1a.

A scanning electron microscope (SEM) was used to assess the abrasion of the geotextiles by comparing the abraded material with an unabraded control sample of each geotextile. Standard SEM procedures were followed (Hearle et al., 1972) to prepare a 10 mm^2 sample of each of the unabraded and abraded geotextiles. The samples were studied at 20x and 100x magnification, and photomicrographs were taken. All photomicrographs were taken at a stage angle of 45° to the scanning electron beam, since the best resolution was achieved at this angle. Although 20x and 100x magnification is very low for the SEM some experimental work by the writers showed that

Fig. 1 ASTM Rotary Platform, Double Head Abrasion Tester.

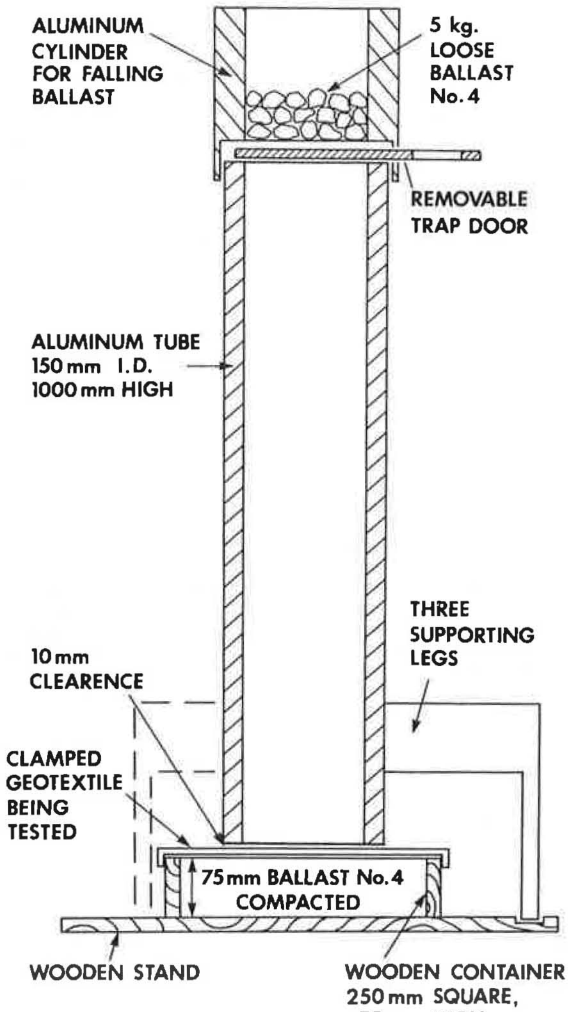

Fig. 2 Sketch of Geotextile-Ballast Impact Abrasion Test Apparatus.

resolution, depth of field and overall clarity was much greater with the SEM than with conventional microscopes.

RESULTS

From the testing program, a very large amount of qualitative and subjective information was obtained. The writers have attempted to remove some of the subjectivity of assessing the abrasion, and to simplify the results by only using certain modifiers to describe the processes of abrasion, and ranking those modifiers as minor or major. A listing and description of those modifiers used is given in Table 2. Table 1b describes the processes of abrasion that the eleven geotextiles underwent during the three abrasion tests. Figures 4 to 7 are photomicrographs that show the construction and quality of typical unabraded geotextiles, and various types and degrees of severity of abrasion.

Comparison of abrasion tests

The Rotary Platform, Double Head Procedure of ASTM D1175 was found to wear abrade the woven geotextiles and the resin dipped non-woven geotextiles (geotextiles I and K) well, but in a fashion foreign to geotextiles in a railbed. When the Rotary Abrasion Test was applied to the other non-resin dipped, non-woven geotextiles, the filaments tended to be pushed out of the way of the abrading wheels rather than undergoing abrasion. In many instances, the abrading wheels became clogged with the polymer of the geotextile being abraded, after more than 1000 cycles.

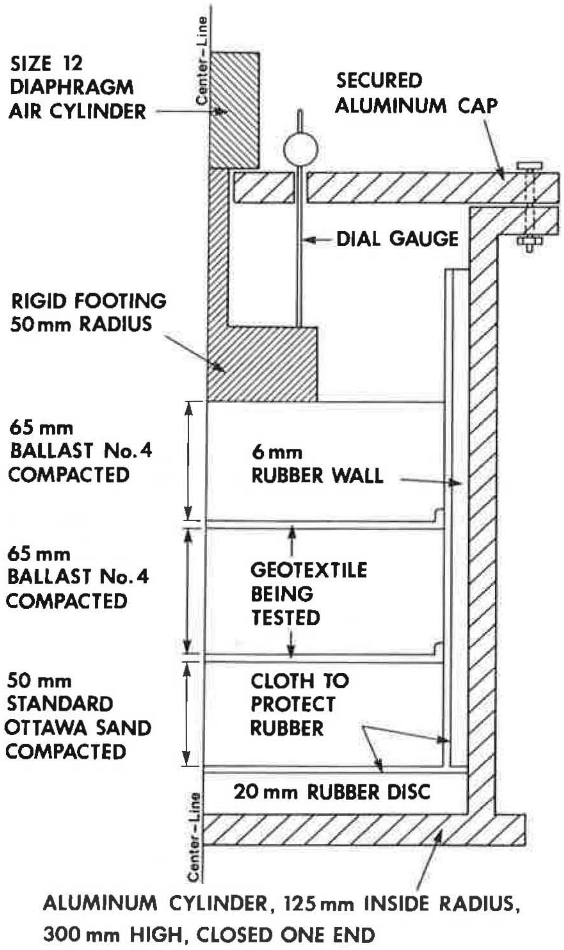

Fig. 3 Sketch of Geotextile-Aggregate Repeated Loading Abrasion Test Apparatus.

The Geotextile-Ballast Impact Abrasion Test was found to perform satisfactorily and simulate the infield condition of ballast emplacement. In most cases, ten drops of ballast were sufficient to cause substantial impact abrasion, and in some cases caused puncturing of the geotextile.

The Geotextile-Aggregate Repeated Loading Abrasion Test also performed very well and simulated in-track repeated loading very well. The ballast-geotextile-ballast test provided substantial wear abrasion to the geotextiles after 100,000 cycles. The ballast-geotextile-sand test seldom abraded the geotextile to any degree and therefore the results are not discussed further. Minor problems were encountered with the cycle counter and the loading cell, however these were minor technical flaws which posed no major problems to the testing program.

Comparison of geotextiles

Woven - The woven geotextiles were found to wear abrade by the process of peeling when subjected to the Rotary Abrasion Test. The amount of abrasion after 1000 cycles was approximately equal for all four woven samples (Table 1b).

After undergoing 10 ballast drops of the Ballast Impact Test, the woven geotextiles frequently showed evidence of peeling, splitting, and being cut. A minor amount of slippage of the filaments was also noted. Geotextile B proved to be the most resistant to impact abrasion while Geotextile D was the least resistant; the multifilaments having been cut all the way through. Geotextiles A and C were abraded to approximately the same degree and to an extent between the Geotextiles B and D.

The most frequent processes involved with wear abrasion of woven geotextiles by the Repeated Loading Test were also peeling, splitting, and being cut. Slipping and flattening of the filaments occurred on two of the samples. Three of the woven geotextile samples were punctured after 100,000 cycles of loading. Geotextile B was not punctured and sustained less abrasion than the other three.

Non-woven - The most frequent processes of wear abrasion, of the non-woven geotextiles having undergone the Rotary Abrasion Test, were peeling and alignment of filaments. Geotextile H was cut and punctured after 1000 cycles. Geotextiles I and K showed evidence of major peeling while the remaining samples showed only minor amounts of wear abrasion.

The common impact abrasion processes seen after 10 ballast drops of the Ballast Impact Test were peeling and being cut. Less frequently the filaments were flattened and fused. Geotextiles G and H were found to abrade the most, and Geotextile G was the only sample punctured by this test. The remaining 5 samples showed approximately the same amount of impact abrasion.

Peeling, flattening, clumping and being cut were the most common abrasion processes noticed after the Repeated Loading Test. Fusing occurred in three of the seven samples. Geotextile H was the least resistant to wear abrasion. Geotextile I was punctured after only 10,000 cycles. Geotextiles F and G were in the mid-

TABLE 1a: PROPERTIES OF GEOTEXTILES — TABLE 1b: TEST RESULTS

GEO-TEXTILE	DESCRIPTION	MASS g/m^2	THICK-NESS mm	ROTARY ABRASION TEST (1000 cycles)	BALLAST IMPACT TEST (10 drops)	REPEATED LOADING TEST (ballast-geotextile-ballast) (100K cycles - except where noted)
A	Woven, polypropylene, flat mono-filaments, black	203	0.7	Pe^1	Pe^2, Sp^1, Cu^1	Pe^1, Sp^1, Cu^2, Pu^2
B	Woven, polypropylene, flat multifilaments, black	730	2.3	Pe^1	Pe^1	Pe^2, Cu^2
C	Woven, polypropylene, flat monofilaments woven with round monofilaments, black	271	0.5	Pe^1, Fl^1	Pe^2, Sp^1, Cu^1, Sl^1	Pe^1, Fl^1, Cu^2, Pu^2
D	Woven, rounded polyethylene monofilaments woven with flat polypropylene multifilaments, black	250	0.6	rounded Pe^2 flat Pe^1	Pe^1, Sl^1, Cu^2, Pu^2 Pe^1, Cu^2, Pu^2	Pe^1, Sl^1, Cu^2, Pu^2, Pe^1, Cu^2, Pu^2
E	Non-woven, needle punched poly-ester mat with polypropylene scrim, fibre length perpend-icular to plane of fabric, white	475	4.0	Al^1, Se^1, Pe^1	Se^1	Pe^1, Fl^1, Cl^1, Cu^1 (10K cycles)
F	Non-woven, continuous spun bonded polypropylene monofilaments, heat set finish, grey	203	0.6	Pe^1, Cu^2	Pe^1, Cu^1	Pe^1, Fl^1, Cl^1, Cu^2, Pu^1
G	Non-woven, continuous needle punched polyester monofilaments, grey	198	1.0	Pe^1	Pe^1, Fl^1, Cu^2, Pu^1	Pe^1, Fl^1, Cl^1, Cu^2, Pu^1
H	Non-woven, continuous spun bonded polypropylene monofilaments encased in nylon sheath and heat bonded, white	137	0.8	Pe^1, Cu^2, Pu^2	Pe^1, Fl^1, Cu^2	Pe^1, Fl^2, Fu^1, Cu^2, Pu^2
I	Non-woven, continuous needle punched, double bonded polyester monofilaments, partially resin treated, blue and white	455	3.3	Al^1, Pe^2	Pe^1	Pe^1, Fl^1, Fu^1, Cu^2, Pu^2 (10K cycles)
J	Non-woven, continuous needle punched polyester monofilaments, grey	415	2.9	Al^1, Pe^1	Pe^1	Pe^1, Fl^1, Fu^1, Cu^2, Pu^1
K	Non-woven, continuous needle punched nylon with polypropylene scrim, resin dipped, black	550	4.5	Al^1, Pe^2	Pe^1, Fl^1, Fu^1	Pe^1, Fl^1, Cl^1

TABLE 2 : DESCRIPTION OF ABRASION PROCESSES

PROCESS	SYMBOL	DESCRIPTION
Aligned	Al	Previously non-aligned filaments be-come somewhat aligned in a preferred direction. Limited to non-woven geotextiles.
Clumped	Cl	Individual filaments form a clump. Limited to non-woven geotextiles.
Cut	Cu	Individual filaments are first cracked and then cut in the transverse direc-tion of the filament.
Flattened	Fl	The thickness of the individual fila-ments is reduced while the width is increased to produce flattening.
Fused	Fu	Individual filaments are fused to-gether; usually accompanyed by flattening.
Peeled	Pe	Small slivers of individual filaments are partially or totally peeled from parent material.
Punctured	Pu	Individual filaments are abraded by various processes and the geotextile develops a hole, thus becomes punctured.
Separated	Se	Individual filaments become separated. Limited to non-woven geotextiles.
Slipped	Sl	Individual filaments of the warp or weft slip along the other and move either closer together or further apart Limited to woven geotextiles.
Split	Sp	Individual filaments are first cracked and then split in the longi-tudinal direction of the filament.
Superscript 1 :		minor amount of abrasion
Superscript 2 :		major amount of abrasion

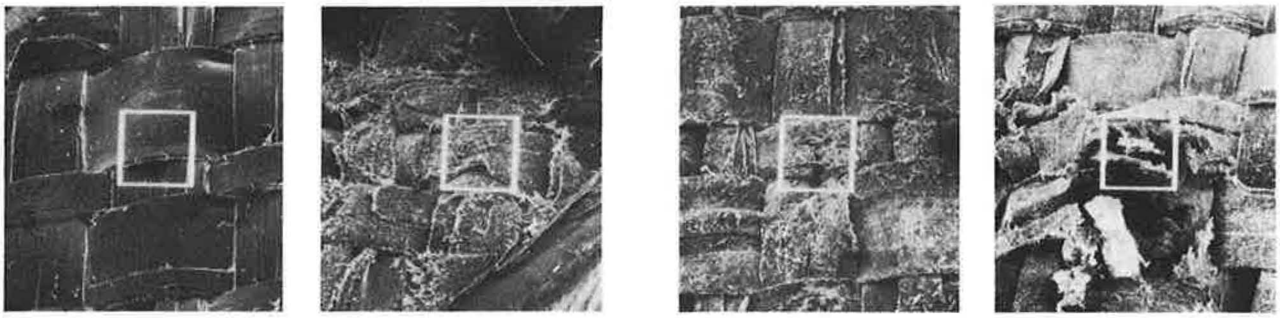

Fig. 4 GEOTEXTILE A (scale bar is 500 microns)
(a) Unabraded
(b) Rotary Abraded (1000 cycles)
(c) Ballast Impact Abraded (10 drops)
(d) Repeated Loading Abraded (100,000 cycles)

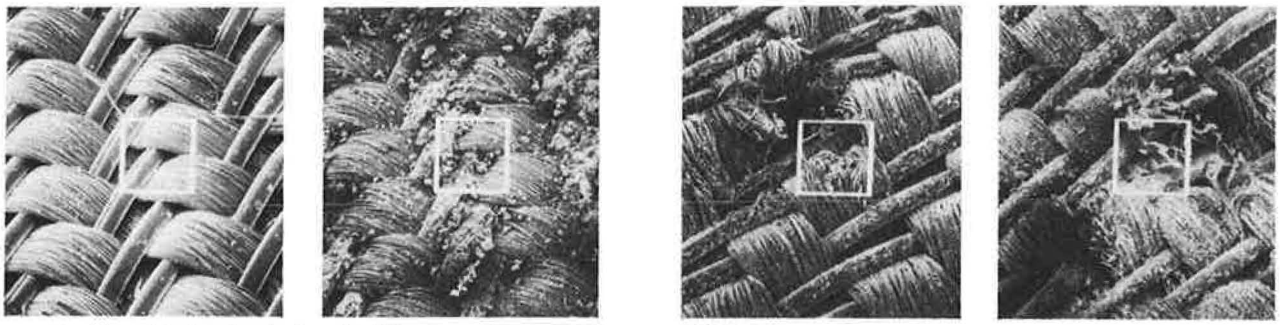

Fig. 5 GEOTEXTILE D (scale bar is 500 microns)
(a) Unabraded
(b) Rotary Abraded (1000 cycles)
(c) Ballast-Impact Abraded (10 drops)
(d) Repeated Loading Abraded (100,000 cycles)

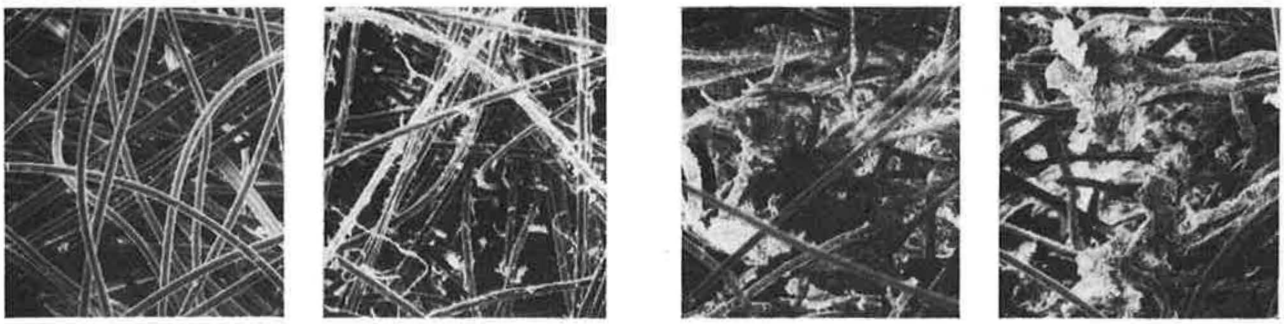

Fig. 6 GEOTEXTILE G (scale bar is 100 microns)
(a) Unabraded
(b) Rotary Abraded (1000 cycles)
(c) Ballast Impact Abraded (10 drops)
(d) Repeated Loading Abraded (100,000 cycles)

Fig. 7 GEOTEXTILE K (scale bar is 500 microns)
(a) Unabraded
(b) Rotary Abraded (1000 cycles)
(c) Ballast Impact Abraded (10 drops)
(d) Repeated Loading Abraded (100,000 cycles)

range of wear resistance. Geotextile J was slightly more resistant than Geotextile G. Geotextiles E and K showed least abrasion and were the only two which were not punctured. (The test on Geotextile E was only taken to 10,000 cycles before a failure in the apparatus stopped the test.)

Woven vs. Non-woven - Some general comments can be made with regards to the abrasion resistance of woven vs. non-woven geotextiles by these three tests. In the Ballast Impact Test the non-woven geotextiles appeared much more resistant to impact than the woven materials. The Repeated Loading Test was found to give the most consistent amount of abrasion to both types of materials. Both woven and non-woven geotextiles were found to abrade about the same amount, albeit by slightly different processses. As mentioned previously, because of the test technique associated with the Rotary Abrasion Test, no comparisons could be made between the woven and non-woven geotextiles for this test procedure.

CONCLUSIONS

A testing program involving three abrasion tests and eleven geotextiles (four woven and seven non-woven) has been carried out. Based upon the results of this study, the following conclusions can be made.

The Rotary Platform, Double Head Procedure of ASTM D1175 was found to wear abrade the woven geotextiles primarily by the process of peeling. However, the test did not simulate impact abrasion caused by ballast emplacement, or wear abrasion of geotextiles in ballast under repeated wheel loadings. This test did not perform well for non-resin dipped, non-woven fabrics.

The Geotextile - Ballast Impact Abrasion Test was found to simulate impact abrasion by the processes of peeling, splitting and being cut for woven material, and peeling and being cut for non-woven material. Ten ballast drops were found to be sufficient to cause substantial impact abrasion. In general, non-woven geotextiles were found to be much more resistant to impact abrasion than woven geotextiles. The thicker woven and non-woven geotextiles were generally more impact abrasion resistant.

The Geotextile - Aggregate Repeated Loading Abrasion Test, at the ballast-geotextile-ballast interface, simulated wear abrasion well. The common processes of abrasion shown by the woven geotextiles were peeling, splitting and being cut. Those for the non-woven geotextiles included peeling, flattening, clumping and being cut. One hundred thousand cycles was found optimum to provide substantial abrasion. For both the woven and non-woven materials, the thinner and lighter weight geotextiles showed less resistance to wear abrasion than the thicker and heavier geotextiles. The woven and non-woven materials were found to abrade approximately the same amount. The ballast-geotextile-sand test seldom abraded the geotextile to any significant degree for either the woven or non-woven geotextiles.

RECOMMENDATIONS

From the results of this study, the writers make the following recommendations:

(1) The Geotextile - Ballast Impact Abrasion Test and the Geotextile-Aggregate Repeating Loading Abrasion Test should be used to test the impact and wear abrasion, respectively, of geotextiles for railroad bed use.

(2) Further testing should be carried out so that the abrasion resistance of individual geotextiles can be assessed.

LIMITATIONS

This study was designed to evaluate three abrasion tests, and assess how they simulate impact and wear abrasion of geotextiles during construction and rehabilitation of railroad beds. The impact and wear abrasion of the eleven geotextiles were successfully assessed using qualitative and subjective evaluations of scanning electron microscope photomicrographs. This study should not be construed as a quantitative evaluation of the abrasion resistance of the individual geotextiles tested.

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