In-Track Performance of Geotextiles at Caldwell, Texas

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ABSTRACT

A performance test of geotextiles in track was performed jointly by the Monsanto Corporation and Southern Pacific Railroad. The test site at Caldwell, Texas, was chosen because of the poor subgrade conditions. The track was instrumented to determine the influence of the geotextiles on track behavior. The instrumentation measured the extent of the anticipated geotextile functions of reinforcement, subgrade moisture transport, filtration, and separation. There was no evidence of reinforcement or moisture transport, but filtration and separation appeared to be the main advantages.

In November 1977, an extensive field investigation was begun of geotextile performance and the associated influence on track behavior, which was a joint project of the Monsanto Corporation and Southern Pacific Railroad. The test site was located in Caldwell, Texas, in an area with significant track maintenance problems resulting from poor subgrade performance. The subgrade soil is comprised of a medium-to-soft consistency, highly expansive clay, which typifies some of the worst soil conditions under which geotextiles are placed.

The geotextiles were installed in a new siding constructed alongside the main line track. New track construction was selected for the test to eliminate problems related to ballast pockets and undercutting programs that would have been experienced if the fabric and instrumentation had been placed in existing track. The main line carries about 10 million gross tons (mgt) per year, which is considered moderate for a main line track.

The test was planned with the objective of determining the extent to which fabrics perform the anticipated functions of (a) reinforcement, (b) subgrade moisture transport, (c) filtration, and (d) separation. Extensive instrumentation was required to differentiate the role that each mechanism played in a given test section. Figure 1 shows the subgrade instrumentation that was installed in each section.

TEST SECTION CONDITIONS

The existing and design grades at each of the six individual test sections are shown in Figure 2. Test Sections 1 through 4 were constructed with nonwoven fabrics placed on the subgrade. The properties of the geotextiles are given in Table 1. Section 5 was a control section with no fabric, and Section 6 was a cement-stabilized zone. Section 6 was used to compare the performance of a conventional, but expensive, method of subgrade stabilization with the performance of the various fabric sections. The length of each of the fabric sections and the cement-stabilized section was 300 ft, whereas the control zone was only 150 ft in length. The control site was made shorter because it was believed that this track section might fail or experience a large amount of settlement.

An 8-in. layer of lightly cement-stabilized soil was compacted over the natural soil of the entire test area to provide a zone of intermediate strength between the ballast and subgrade. The natural soil had a range of liquid limits between 50 and 85 percent, and a plastic index of between 27 and 55 percent, and is therefore a CH-type soil (inorganic clay of high plasticity) under the Unified Classification System. The natural soil was about 95 percent saturated. The compacted soil layer is classified as a CL-type soil (clay of low plasticity). Field California Bearing Ratio (CBR) tests were performed on the compacted soil at three locations within each test section. The average CBR values at 0.1 in. penetration for the six sections were 24, 23, 21, 20, 32, and 15, respectively. The CBR values were much greater than would be expected for clayey loam, due to the surface cement stabilization and heavy compaction.

The effects of swelling soil were seen in the top-of-rail surveys and soil moisture measurements obtained periodically over a period of 1.5 yr. Upheaval of the track was observed after a hard rain, but the effect of this soil swelling on the dynamic instrument response should not have been appreciable. After the various fabrics were placed in Test Sections 1 through 4, 8 in. of ballast were placed over each section. No subballast was used. Section 6 had the ballast resting on 12 in. of cement-stabilized rock screenings.

TRACK LOADINGS

Switcher locomotives, running at speeds between 2 and 50 mph, provided the load input to the track structure for those tests that required a load. The cumulative wear on the track was provided by revenue trains that were allowed to run over the test sections. Unfortunately, records of the amount of actual traffic tonnage passing over the test sections were not kept. However, because approximately 50 percent of the main line traffic was diverted onto the siding test section, it may be assumed that the siding received about 5 mgt per year (i.e., one-half of the single track total of 10 mgt per year).

QUASI-STATIC TRACK SYSTEM RESPONSE

As mentioned earlier, there are four postulated mechanisms by which a geotextile is believed to influence track behavior in general:

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- Reinforcement,
- Moisture transport,
- Filtration, and
- Separation.

The data from instrumentation that are used to measure such influences will be presented next. Near the end of the paper, the measurements are reviewed to determine if and how much any of the preceding mechanisms influenced behavior.

Soil Moisture Measurements

Soil moisture in the compacted clay loam and the natural clay subgrade was measured to monitor the water content (relative percentage ratio of pore water to soil solids). A smaller seasonal change in soil moisture contents in the fabric test sections as compared to the control section would indicate that a fabric may keep the subgrade drier.

Drainage in the test sections was dependent on the topography and local soil properties. Figure 2 shows the grade conditions for the overall test site. The steeper grade in Section 1 provided better drainage; however, this section also received runoff from Sections 2 and 3. Thus, various combinations of grade and watershed did not appear to favor any particular section.

Three methods were used to monitor the soil water content: (a) manual corings, (b) electrical resistance transducers, and (c) electrical capacitance transducers. The last two methods (those using instrumentation) gave values of moisture content that were close to those of the field corings. However, the instrumentation responses were flatter and did not show the increase resulting from the rainy months of March through June as did the samples recovered from the field. Because the water content measurements from the manual corings are believed to be the most reliable, only the data from the field corings will be given. Soil samples were obtained every 6 in. to a depth of 24 in. at the middle of each test section. Figure 3 shows the variation of subgrade water content in the test sections over approximately 1.5 yr. Figure 4 shows the test section differences between the seasonal maximum and minimum soil moistures that occurred during the 17 months.

Pore Water Pressures

Pore water pressures in the natural subgrade were monitored using piezometers. It was believed that subgrade moisture transport in the fabric test sections might be apparent from reduced pore water pressures compared to the control section. The piezometers were implanted within the subgrade in each section in a plane perpendicular to the rails. Shallow piezometers were placed 15 in. beneath the finished subgrade at locations below the south edge of the ties, the south rails, and the centerline of

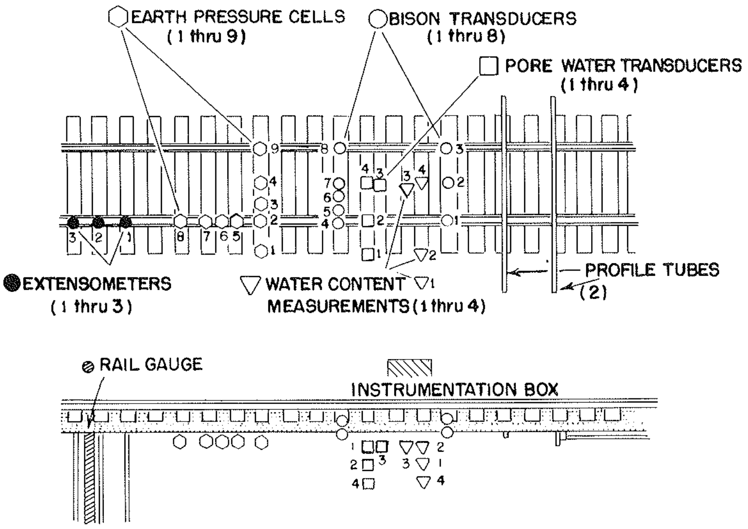

FIGURE 1 Schematic diagram showing typical subgrade test instrumentation.

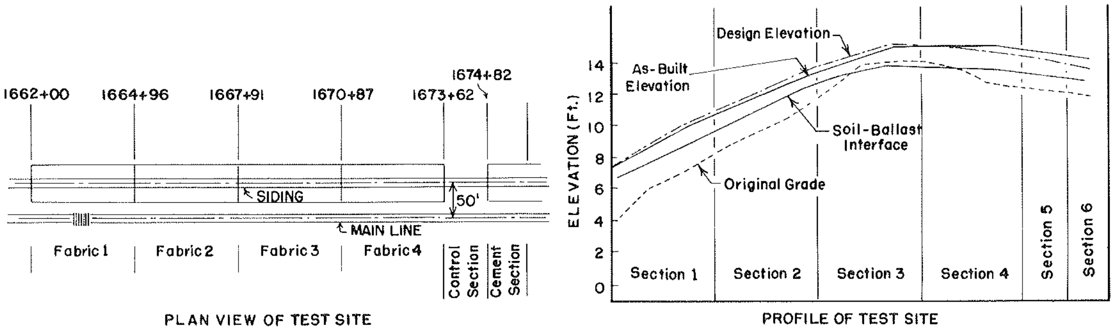

FIGURE 2 Caldwell test site configuration.

TABLE 1 Physical Properties of the Caldwell Test Site Geotextiles

	Fabric			
Property	1	2	3	4
Weight (oz/yd^2)	10.7	10.7	6.1	6.7
Thickness at 0.03 bar (mils)	173	99	22	78
Porosity (%)	91	90	60	92
Density (kg/m^3)	83	144	364	114
Puncture strength (lb)	113	143	74	88
Puncture toughness (lb)	40	34	24	25
Burst strength (psi)	344	458	270	311
Grab strength (lb)				
MD[a]	165	279	233	238
TD[b]	271	301	225	184
Apparent elongation (%)				
MD	129	66	61	63
TD	112	61	75	75
Toughness (lb)				
MD	106	92	71	75
TD	152	92	84	69
Trap. tear strength (lb)				
MD	62	114	76	95
TD	88	109	102	86
Abrasion (grab strength) (lb)	104	177	184	71
Lateral permeability (cm/sec)				
At 0.24 bar	0.27	0.32	0.06	0.38
At 2.00 bar	0.08	0.13	0.01	0.14
Normal permeability				
cm/sec	0.57	0.45	0.02	0.44
liter/sec/cm^2	0.022	0.022	0.004	0.034
Equivalent opening size	50	Unknown	200	Unknown
Denier	7	7	12	7
Polymer	Polypropylene	Polyester	Polyester	Polyester
Structure	Needled	Needled	Thermal-bonded	Needled

[a] Machine direction.
[b] Transverse direction.

the siding. An additional piezometer was placed to a depth of 4 ft beneath the finished subgrade at the centerline of each test section.

Maximum static positive pore water pressures would occur if the water table is assumed to be at the surface of the subgrade. Thus, the maximum positive pore water pressures measured at Caldwell should be 0.54 psi for the shallow piezometers and 1.73 psi for the deep piezometers, based on the depth below the water table. However, pore water pressures in excess of 0.54 psi (some approaching 3.6 psi) were measured by the shallow piezometers at Sections 1-3, and 6, which conflicts with the maximum pore water pressure model just mentioned.

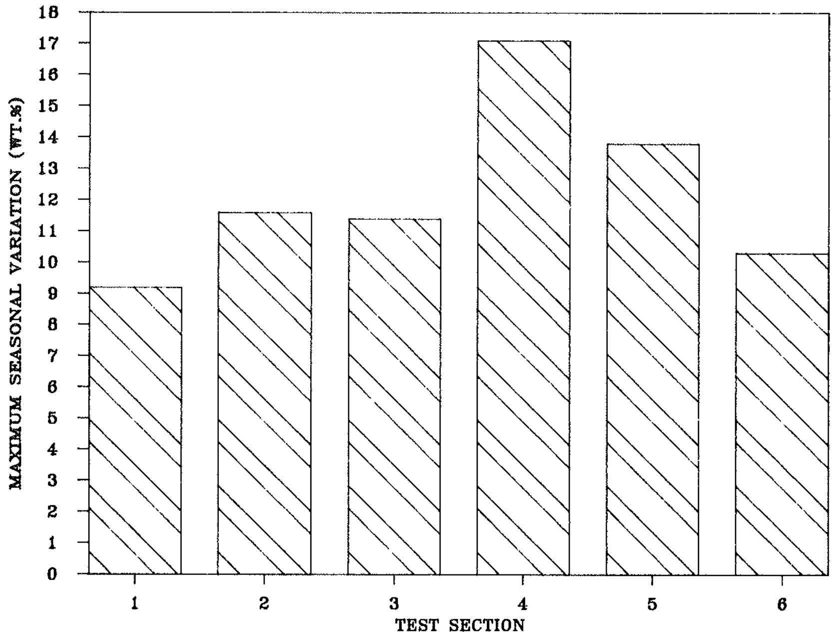

FIGURE 3 Maximum seasonal variations in soil moisture content from July 1978 to March 1980 for Sections 1-6.

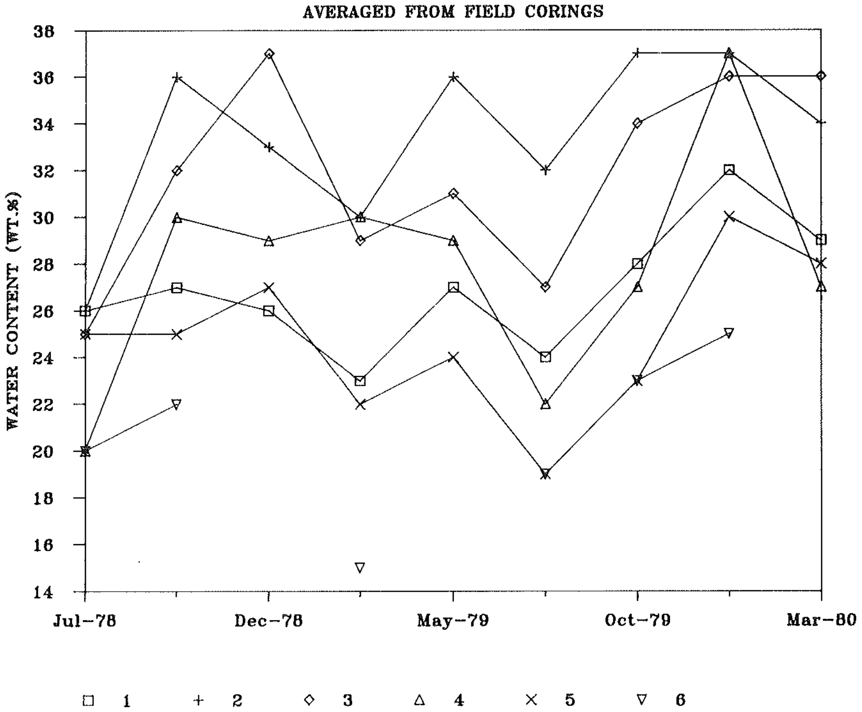

FIGURE 4 Variations in average soil water content with time in Sections 1-6.

Excess positive pore water pressures would lead to reduced subgrade strengths and increased settlements, caused by reduced effective stress. However, Sections 1, 2, and 6 did not experience significant settlements and certainly did not appear to be showing any signs of weak or failing subgrades.

Although there were erratic readings from a few of the piezometers, the others gave reasonable measurements. From these data, the reduced pore water pressures expected to be seen if soil moisture transport was occurring were not apparent. Therefore, no systematic test section differences were observed with this instrumentation.

Subgrade Geometry

Static vertical extensometer readings were recorded to monitor the vertical movement of the soil-ballast interface with respect to a point 10 ft below. The static extensometer readings are shown in Figure 5. All of the curves show a consistent trend in the rise and fall of the interface. Section 5, the control section, clearly experienced greater vertical settlements than the remaining sections. Note also that the vertical movement of Section 3 began to accelerate rapidly during December 1979. The failure of Section 3 occurred in January 1980, as shown in Figure 5.

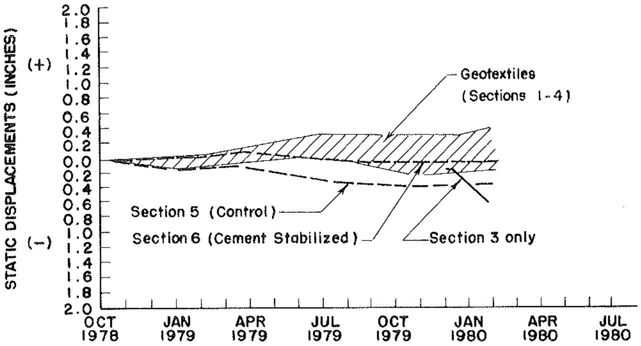

FIGURE 5 Extensometer data showing static soil displacement variations with time in Sections 1-6.

Track excavations were made in each of the fabric sections to observe the transverse subgrade profile under both a tie and a crib. Elevations were taken at the top of the fabric in each excavation before it was removed to reveal the subgrade. Large subgrade displacements were indicated for Section 3. The excavation in Section 3 was made in an area where the top-of-rail (TOR) profile had indicated large settlements. This provided further evidence of the soil-related failure of Section 3. The subgrade profiles from all of the geotextile sections and the control section showed a depression of the subgrade below the tie-rail seats. The depth of this depression ranged from less than 1 in. in Section 4 to more than 6 in. in Section 3.

The most significant finding in the excavations was made at Site 3 where a layer of weak clay slurry was located just under the fabric. The penetrometer unconfined compression strength of the clay slurry was less than 0.25 tons per ft^2. The slurry layer appeared to be extruding from beneath the fabric. The existence of this layer pointed to a near surface soil failure as contributing to the excessive settlement in Section 3. The low permeability of the fabric appeared to be the cause of the slurry formation. This problem site will be discussed in greater detail later.

DYNAMIC TRACK SYSTEM RESPONSE

Subgrade Response--Earth Pressures

The transducers for measuring vertical earth pressures were installed 3 to 4 in. below the top of the

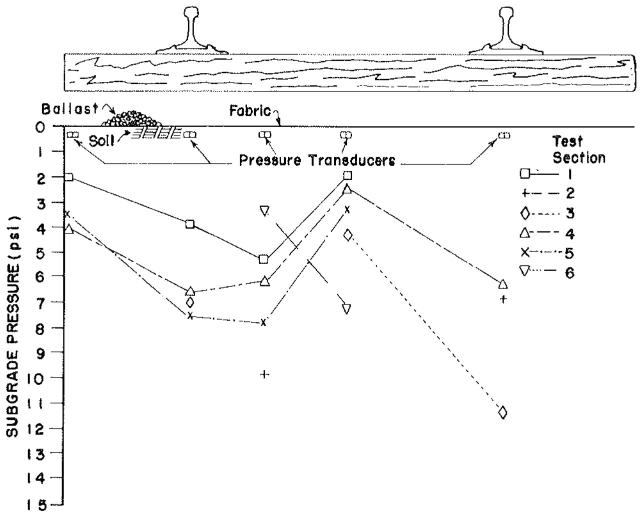

FIGURE 6 Subgrade pressures under one tie in each of Sections 1-6.

subgrade. Figures 6 and 7 show the transverse and longitudinal layout of the transducers in the soil. The earth pressure measurements shown in these figures were obtained by selecting the maximum pressure registered by each transducer during each locomotive pass. These maximum pressures were generated under the wheel loads of switcher locomotives traveling at velocities ranging from 2 to 50 mph. Because the maximum pressures varied somewhat with locomotive speed (a small variation in most cases and with no definite trend), the average for each of the various speeds was calculated and plotted in Figures 6 and 7.

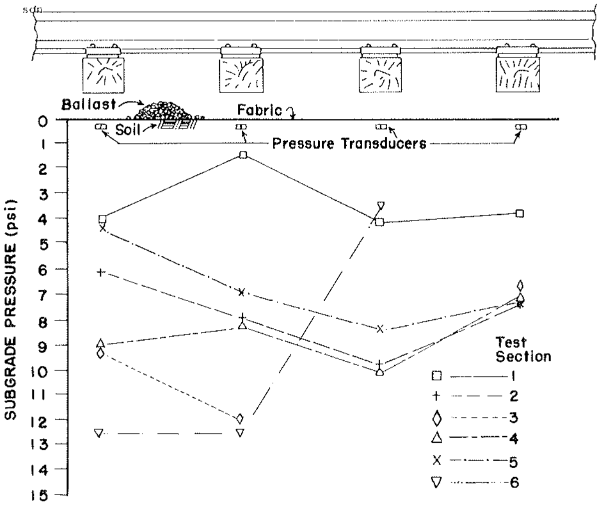

FIGURE 7 Subgrade pressures under four ties in each of Sections 1-6.

The transverse and longitudinal earth pressure measurements showed approximately the same pressure profiles for each site. No significant differences could be observed between the pressure profiles in the fabric sections and those in the control section.

Elastic Subgrade Deformations

Measurements of elastic subgrade deformations under load were obtained using three extensometers per section, which were installed under the rail-tie seats. The mean values obtained under loading are plotted in Figure 8 for the respective test dates. The elastic deformations measured in Sections 2-4, and 6 showed the same climatic variations, with Section 6 having consistently smaller amplitudes. General weather data obtained from Caldwell, Texas, showed that March through June were months that had significant amounts of rainfall, which would explain the increase in dynamic displacements in all but Section 5.

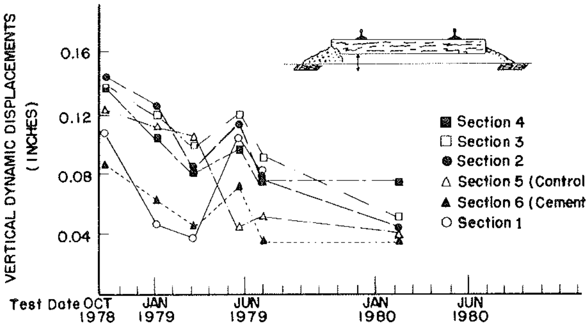

FIGURE 8 Variations in mean values of elastic deformation under load at the ballast/subgrade interface with time, for Sections 1-6.

The anomalous behavior of Section 5 during the wet season was shown by decreasing elastic deformation, while the other sections were experiencing increasing deformations. Section 1 also had anomalous behavior, as evidenced by the wide range in deformation with the seasons. The soil moisture content data did not indicate that the soil in Section 1 experienced greater variation of moisture content; the moisture content in Section 1 was the most uniform during this period.

Because there was no consistent trend in subgrade elastic deformations between test sections, no section differences are noted. The control section had lower-than-average elastic subgrade deflections.

Superstructural Response--Tie Plate Loads

The portion of the wheel load that was distributed to the single tie over which the wheel was located was measured at one tie in each section, using a load cell tie plate. The load cell tie plates were installed just before the time of measurement and then replaced with ordinary tie plates after the testing was completed.

The maximum tie plate loadings for all six sections were 19, 18, 14, 10, 11, and 20 kips, respectively. Sections 1, 2, and 6 appeared to have the largest loads. However, tie loads can be variable from one tie to the next, even in new construction. Tests elsewhere have shown that the percentage of a wheel load taken by the tie directly under that wheel may vary between 20 and 50 percent (1), depending on the tie support conditions and rail stiffness. In these tests, the range of the tie loads divided by the wheel loads (about 33 kips) for all six sections was between 30 and 60 percent. Because the test results were within the natural variations of the tie load spectrum, and because only one tie per section was instrumented, data from the instrumented tie plates could not be used to explain the observed differences in test section behavior.

Tie Strains

The tie strains were measured by gauges attached to the top of one tie in each test section. This enabled the dynamic bending strains in the longitudinal plane of a tie in each section to be monitored. The ties in Sections 5 and 6 were straining somewhat more in the tie middle than near the rail seats, whereas the fabric section ties were strained more uniformly. However, as mentioned previously, the tie support conditions, and, therefore, the bending, could vary considerably from tie to tie. Therefore, because only one tie per section was instrumented, differences in section response could not be confirmed from these data.

BALLAST CONTAMINATION

Filtration and separation are two of the attributes most commonly associated with the use of geotextiles in railroad applications. To assess the performance of the fabric sections with respect to these two characteristics, samples of ballast, soil, and fabric were taken from the field for laboratory analysis.

Differentiating the subgrade fines from fines of other sources, for example, from ballast abrasion, windblown, and so forth, was essential to evaluating the performance of the various geotextiles. Section 6, the cement-stabilized section, played a key role in this investigation, because it contained fines from all sources other than those associated with the subgrade. Assuming reasonably uniform ballast and surface conditions, the contaminating fines measured in Section 6 should represent a control for the other test sections.

Ballast samples were taken at uniform increments of depth below the top of the ties in Sections 1 through 6. Additional samples were obtained from the top of, and beneath, the fabric in Sections 1 through 4. Samples were also taken at the soil-ballast interface, and at the top of the cement at Sections 5 and 6, respectively. Samples were obtained from holes dug by hand in the ballast. A water spray mist was used to prevent the fines from being displaced due to the sampling disturbance. Approximately 700 to 800 g of ballast were taken at each depth.

The amount of contamination, as quantified by measuring the amount of fines that passed through a No. 200 sieve (0.074 mm), consisted of both silt and clay-sized particles, and were assumed to be representative of the ballast contamination.

Mean values were established for the percentage of contamination versus depth data from each test section, and are presented in Figure 9. In the ballast above the level of 12 in. from the top of the tie, only Sections 3 and 5 had contamination in excess of that measured in Section 6 (the "control" section in this case). (Note the contamination of the ballast just above the fabric. Section 5, with no fabric, had significantly more contamination at this level than the remaining sections, and only Sections 3 and 4 of the fabric sections had contamination greater than Section 6.)

In addition to the amount of contamination, laboratory hydrometer analyses were performed to measure the percentage of clay particles in the contaminant fines. Clay particles in the contaminant can originate only as windblown particles or in the subgrade. Crushing and abrasion of the ballast would produce coarser silt-sized particles. The subgrade beneath the track consisted of both clay and silt-sized particles; therefore, the presence of excessive amounts of clay fines would indicate a filtering of the silts by the fabrics, as the fines tried to pass through the fabric.

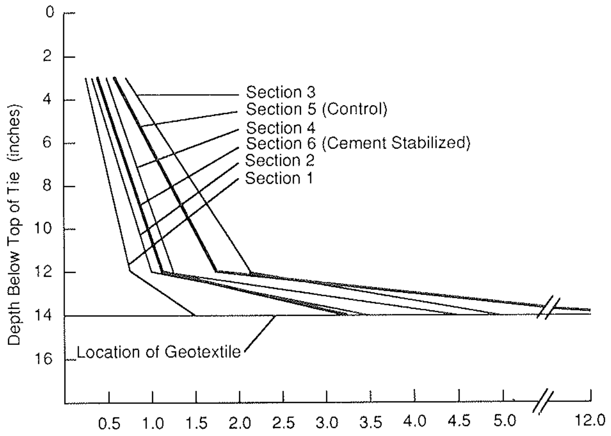

FIGURE 9 Percentage of fines passing a No. 200 sieve versus sampling depth in Sections 1-6.

The average percentages of clay particles in the contaminant fines for Sections 1 through 6 were, respectively, 50.3, 45.7, 43.6, 40.6, 32.6, and 25.3. Therefore, using Section 6 as the control, it appears that the fabric sections received much of their subgrade contamination in the form of clay particles. Because Control Section 5 (the most fouled section) exhibited a significantly lower percentage of clay within its ballast fines, this indicates that large quantities of subgrade silts in addition to the clay were moving into the Section 5 ballast because no fabric was present. This substantiates the filtering capabilities of the fabrics with respect to silt-sized particles.

The quantities of clay-sized particles present within the ballast in Fabric Sections 1, 2, and 4 were between 2 and 3 percent by weight of the total ballast sample. Fabric Section 3 and Control Section 5 had about 8 percent clay fines near the bottom of the ballast layer. [In Fabric Section 3, this may be explained by the extrusion of the soil-slurry that had built up just under the fabric.] Percentages less than 4 or 5 are normally considered negligible in that they will not influence the ballast performance. The amount of clay in Sections 3 and 5, however, may contribute to a degradation of the engineering properties of the ballast. An example of such degradation is the possible increased lateral spreading of the bottom layer of ballast under the lateral shear forces caused by traffic. Excessive track settlement can result. It appears that the use of fabrics can control the pumping of silt-sized particles into the ballast. Fabrics will allow a small amount of clay to pump into the ballast. However, this amount of clay will be significantly smaller than would have occurred if no fabric had been used.

PROPERTIES OF RECOVERED GEOTEXTILES

After 17 months of service, several ties were removed and the ballast was excavated so that samples of fabric could be taken from each test section. The fabric samples were taken to a laboratory, tested for their permeability, both in-plane and normal to the fabric, and compared with the permeability of a clean sample of fabric (shown as the control sample in Figure 10). Also, the strength in tension, as measured by the Grab Tensile Strength test, was determined.

Figure 10 shows the measured decrease in fabric permeabilities when tested in the soiled condition

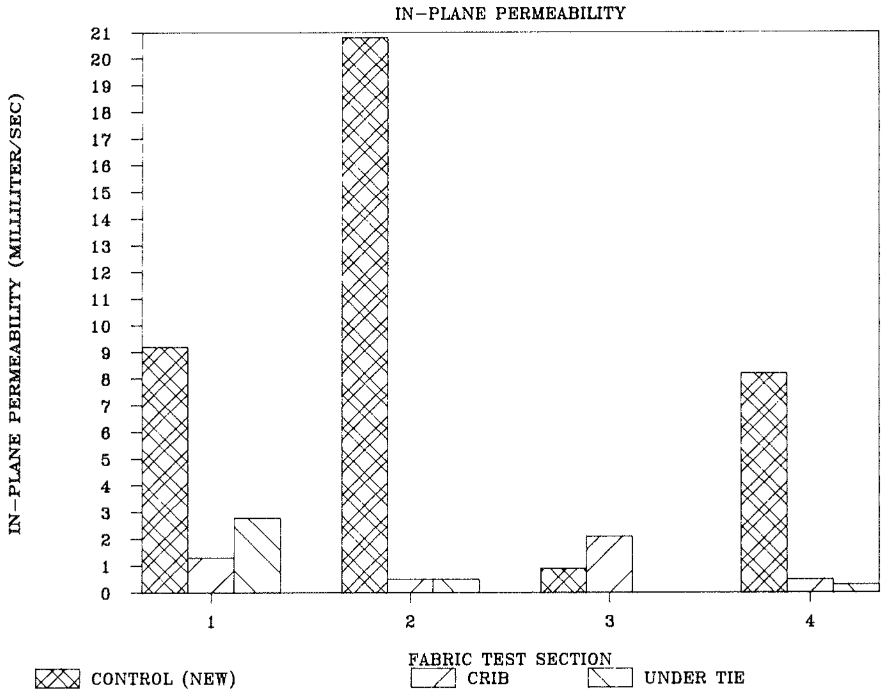

FIGURE 10 In-plane permeability of geotextiles recovered from the field and tested at a pressure of 3.4 psi, applied normal to the surface.

after removal from the field. As shown, the in-plane permeability of the fabric samples after 17 months in track have decreased by as much as a factor of 100. The fabric in Section 1 retained the greatest percentage of its initial in-plane permeability. The test performed on the fabric from Section 3 appeared to show a gain in permeability in the field; however, this test was reported by the technician to be in error. The fabric in Section 3 is known to have clogged more severely in the field than any of the other fabrics based on the observed performance in the field.

A combination of visual and microscopic inspections revealed that all of the fabrics had soil particles in the voids of the fibers and on the fabric surfaces. Fabric 1 had the least amount of soil in the fibers, while the other three fabrics had a greater (approximately equal to each other) degree of soil particles in them. These observations confirmed the laboratory permeability results.

The tests that were conducted to determine the permeability normal to the plane of the fabric again showed the fabric from Section 1 to have the smallest percentage decrease and the greatest permeability. However, even with permeability decreases on the order of 100, the soiled fabric permeability was still much greater than that of the soil itself.

It appears desirable to permit a certain amount of clay to pass into and through the fabric, while the silt is retained in the surrounding soil. If some clay fines are not allowed to pass into the fabric, they are retained just under the fabric and, after a time, may form a weak soil layer. The behavior of pore water pressure at the soil-fabric interface is crucial to system performance. The soil immediately adjacent to the fabric apparently has a tendency to increase in water content as a result of soil suction and local shearing by ballast particles (2). Hoare has found that the water content of this thin layer of clay soil layer may increase to the liquid limit and beyond. The fabric must remain sufficiently permeable to allow pore water, carrying the clay fines under pressure from transient loads, to escape into the fabric. In other words, the filtration properties of the geotextile should not be 100 percent efficient.

As evidence of this phenomenon, consider the fabric-related soil failure in Section 3. A derailment occurred that was directly related to the weak layer of clay particles that built up just under the clogged fabric. Although it is not clear to what extent the derailment was due to the differential rail settlement caused by the weak soil in Section 3, or the track sliding horizontally under load, or both, the failure was clearly exacerbated because of an impermeable geotextile. Ballast sliding laterally on top of the fabric due to a low coefficient of friction of Fabric 3, also contributed to the track settlement, although to a lesser degree than soil failure, which caused 6-in. rutting.

The grab strength test was used to determine the tensile resistance to tearing, when subjected to a slowly increasing load applied to either end of a standard sized strip. Fabric in a soiled and wet condition was tested in this manner; the results are shown in Figure 11 for samples recovered from under the tie and in the crib area. The fabric with the largest loss of strength, as compared to a new control sample, was Fabric 1, which exhibited a 56 percent decrease. Fabric 2 had the least amount of strength loss, with only a 35 percent decrease.

A visual inspection at the time of fabric sampling from the field revealed that Fabrics 3 and 4 had the most holes from tamper and traffic-induced ballast puncturing. Also, despite the relatively low amount of retained grab strength, Fabric 1 was observed in track to have the least number of puncture holes. The fabric holes appeared to be caused by puncturing rather than abrasion.

ANALYSIS OF RESULTS

Any final analysis of the effect of geotextiles on track behavior should compare how the track was

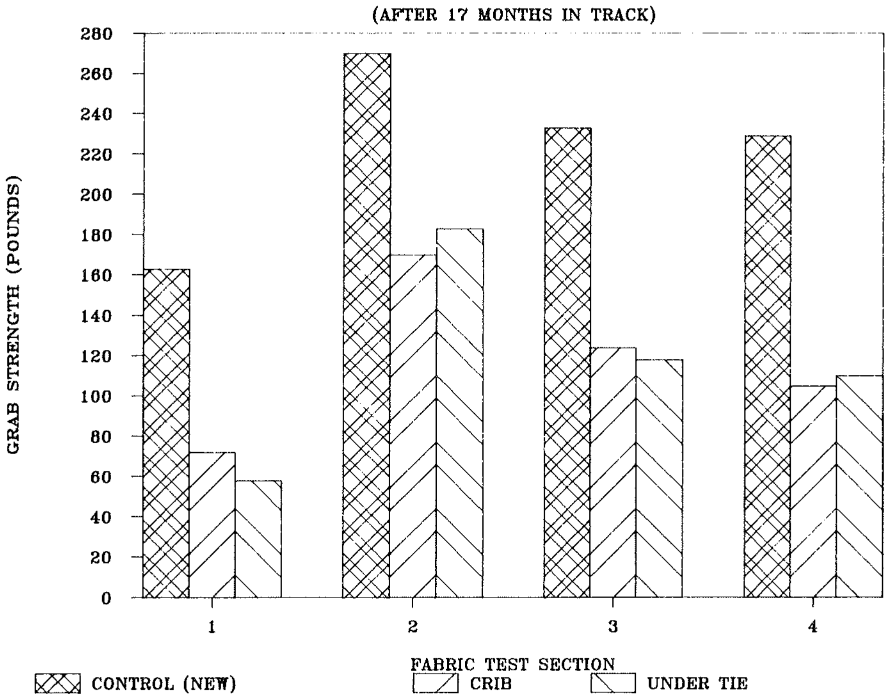

FIGURE 11 Grab strength of geotextiles recovered from the field and tested under wet and soiled conditions (after 17 months in track).

postulated to be improved and determine to what extent, if any, the testing indicated such an improvement. Data gathered over the 1.5 yr of testing will be analyzed in more detail in this section. The four postulated beneficial effects mentioned earlier will now be reviewed in light of what the various track measurements indicated.

Reinforcement

If track reinforcement was occurring, these effects would probably manifest themselves in a decreased amount of vertical deformation under load and decreased pressure transmitted to the subgrade. A review of the data from the subgrade pressure and extensometer transducers indicated that no such reinforcement effect was observed, when the instrument readings of Fabric Sections 1 through 4 were compared to those of the control (Section 5) and the cement-stabilized (Section 6) locations.

The control section did experience somewhat more ballast/soil interface settlement than the other sections (Figure 5). However, this most likely is due to ballast penetration into the subgrade in Section 5. Therefore, rather than a reinforcement function, the decreased settlement in the fabric sections is probably attributable to the separation function of geotextiles.

Subgrade Moisture Transport

Another anticipated benefit of geotextiles, that of moisture transport in the subgrade, could be assessed by the soil moisture measurements and the pore water pressure readings. Although the soil moisture measurements were not consistent between the different measurement methods, there was still enough evidence to conclude that there was no apparent subgrade moisture transport in the fabric sections as compared to the control section. The maximum seasonal variation of subgrade moisture content in Section 5 was not significantly greater than that of the average of all of the fabric sections (see Figure 4).

The pore water pressure readings, although somewhat difficult to interpret, also did not support the moisture transport mechanism. The reduced pore pressures that would be expected to be observed in the fabric sections, relative to the control section, if the fabrics did transport moisture, were not apparent.

Filtration/Separation

The real success of these geotextiles in separating the layers, and limiting intermixing of the ballast and subgrade, could be seen by comparing the amount of fines above the fabric with the amount at the ballast/soil interface in the control section (Figure 9). The silty and clayey fines in the ballast of each fabric test section could be used to assess the filtration and separation functions of these geotextiles. There was a clear difference within the fabric sections with respect to the amount of subgrade fines contamination in the ballast. Of the fabric sections, Section 1 had the lowest amount of fines in the ballast, whereas Section 3 had the highest.

However, as mentioned previously, filtration should not be 100 percent efficient. Passing some of the clayey fines that have access to the fabric should continue in order to prevent a buildup of these particles and a resulting weak soil layer. The acceptable amount of clay is difficult to determine, but it should not be more than about 3 or 4 percent of the ballast by weight.

Durability

The types of geotextiles in this test allow a comparison of needle-bonded with thermal-bonded fabrics, and polyester with polypropylene fabrics. The thermal-bonded type of fabric structure appears unsuitable for use in railroad track because of its low permeability and low ballast-fabric frictional resistance. The fabric with the polypropylene structure (Fabric 1) seemed to perform best with respect to resistance to both clogging and puncture damage. Although not mentioned before, Fabric 1 had the highest retained filament strength of all the fabrics recovered from the field. The retained strength of filaments from the tops (sides that faced the ballast) of Fabrics 1 to 4 were, respectively, 90, 57, 34, and 56 percent. There was, however, somewhat more abrasion on the surface of Fabric 1. Also, Fabric 1 had the greatest loss in grab strength.

CONCLUSIONS

Geotextiles apparently provide varying degrees of filtration and separation to the track structure. These two functions could be enough to justify the inclusion of fabric in the track. If reinforcement or subgrade moisture transport, or both, also resulted, then this would be an added bonus. However, the data collected from this extensively instrumented test showed no evidence of moisture transport or reinforcement attributable to the fabric.

The graphs of subgrade moisture from the soils (obtained by hand sampling for over 1.5 yr) indicate seasonal changes in the soil in each section, but the observed moisture variations were virtually the same among the fabric sections and the control section. It is in the variation of subgrade moisture that one would expect to observe evidence of fabric-induced subgrade drainage. Reinforcement as a result of fabric membrane support was also not indicated from either the earth pressure measurements or the soil extensometers.

Perhaps one of the most interesting findings was the geotextile-related track failure, which resulted in a derailment in Section 3. The soil failure was in the form of a clay slurry that had built up under a fabric with a low initial permeability. The structure of the polymer (thermal bonded) may have had something to do with the failure as well. Because the clay particles in the compacted clay loam were displaced upwards under the loading conditions, these fines accumulated at the fabric-soil interface. Furthermore, the water in the clay fines did not escape through the fabric because of apparent fabric clogging. This clogging is believed to have been caused by the initially low permeability of the fabric. The low ballast-fabric friction resistance may also have contributed to the excessive settlement in Section 3, because of low lateral ballast restraint.

It appears that the installation of a geotextile that clogs can be more harmful than not installing one at all, as shown by the fact that Fabric Section 3 failed, while control Section 5 was remarkably stable. Even though this particular type of thermal-bonded fabric is no longer used in track, it does illustrate what could happen if a fabric became clogged. With the more permeable fabrics that railroads are using currently, clogging may not occur for many years. However, these fabric properties that resist clogging should be further investigated.

In summary, the Caldwell geotextile tests indicated that these fabrics did not play a direct structural role or modify the soil conditions in an active manner. The benefit of these materials appeared to be in their application as barriers to intermixing of the ballast and subgrade.

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