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Southern Pacific Transportation Co. Utilization of Geotextiles in Railroad Subgrade Stabilization

Les géotextiles dans les fondations de voies ferrées de la Southern Pacific Transportation Company

Southern Pacific Transportation Company field tests and applications have proved that geotextiles should be definitely considered in railroad subgrade stabilization. When an existing track structure is rehabilitated using track plows and track undercutters, installation of geotextile is an economical method of improving subgrade stabilization and reducing future maintenance costs.

New standardized tests for geotextiles need to be adopted which will conform more nearly to the actual application.

Tensile strength is important to any geotextile, but separation, filtration and particularly planar permeability for rapid release of pore pressures are equal or greater in importance to the stabilization of railroad subgrade.

Des essais pratiques et des applications réalisés par la Companie de Southern Pacific Transportation,ont démontré que les matières géotextiles sont définitivement à considérer dans les travaux de stabilisation de la fondation de la voie. Lors de la remise en état d'une structure de voie ferrée au moyen de pelleteuses et de dégarnisseuses, l'emploi de matières géotextiles représente une méthode économique pour améliorer la stabilisation de la fondation et pour réduire les frais d'entretien futurs.

De nouveaux essais standardisés de géotextiles devront éventuellement être adoptés pour les rendre plus conformes aux applications envisagées.

L'effort de traction est un facteur important pour tout géotextile; toutefois, la séparation, la filtration et en particulier la permeabilité plane pour assurer un rapide relâchement de la pression sur les pores, sont égales ou supérieures en importance pour stabiliser la fondation de la voie ferrée.

INTRODUCTION

Subgrade stabilization has always been a problem to the railroads, and this problem has been intensified with progressive increases in traffic speeds and heavier loads. Train delays due to poor track conditions, and the high costs of maintenance due to increase in cost of labor and materials, have given the railroads justification to invest in testing new methods to improve subgrade stabilization at an economical cost. After approximately 17 years of railroad subgrade stabilization by conventional costly methods, in 1965 I conceived the idea of installing a membrane between the ballast and the subgrade to prevent the ballast from penetrating into the subgrade and subgrade fines from protruding into the ballast. In 1975, geotextiles became known and we at Southern Pacific Transportation Company immediately started testing various geotextiles, and in 1977 our company participated with Monsanto Company in building a highly instrumented test site at Caldwell, Texas, using different types of geotextiles. As of this date, our company has installed over 1600 km (1,000 miles) of geotextiles under railroad track structures. This paper is being presented based mostly on my observations of the effects of geotextiles on railroad subgrade stabilization along with tests and inspection of geotextiles removed from under an operating track. In addition, I have tried to learn something about these geotextiles by observing their manufacture in France, Germany, and in the U.S.A., and in discussing their effects on railroad stabilization with other railroads in France and in the U.S.A.

TRACK SUBGRADE REACTION

To understand some conclusions stated in this paper the type of subgrade reaction should be understood. Railroad traffic produces both high magnitude cyclic and direct vibratory loads onto steel rails that rest on cross ties. These cross ties are then bedded in a layer of uniformly graded, angular, coarse, hard-broken rock known as ballast which produces an elastic foundation. Ballast is compacted only under each rail with no compaction under the center portion of the cross ties to prevent center-bounding, and this type of compaction along with the type of ballast materials results in nonuniform distribution of the load onto the subgrade with the load concentrated primarily under each rail. This type of loading causes a progressive permanent deformation. Characteristically, railroads consist of long, narrow corridors with many varying subgrade materials. This, along with heavy traffic tonnage, causes these deformations to vary in depth. Being open graded, railroad structures allow rain water to collect in the subgrade deformations and small ponds of water form in spots of the subgrade resulting in a completely saturated soil with free water. Dynamic, rapid, repeated traffic loads, transmitted to a saturated fine grain soil subgrade, create very high instantaneous pore pressures. If these pore pressures cannot be dissipated rapidly into a free draining material, the fine grain soil will go into a plastic state or even into a liquid state. This not only results in low shear strength, but allows the ballast to penetrate downward and the plastic, or liquid, soils to migrate upward into the voids of the coarse ballast. This phenomenon progressively becomes worse with time as the deformation becomes deeper, forming ballast pockets. This is commonly known by railroaders in the U.S.A. as "pumping track". The depth of the ballast pockets will depend on the type of subgrade materials, frequency and amount of rainfall, and total traffic tonnage. I have often encountered ballast pockets up to 4 m (15 feet), and some as deep as 8 m (30 feet). A deep ballast pocket can saturate the outer slope or base of an embankment resulting in a shear failure.

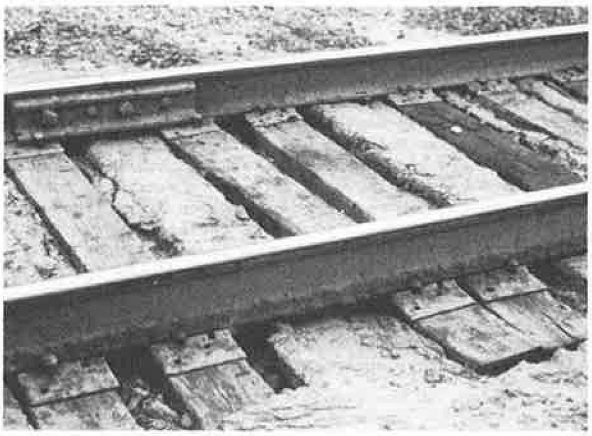

Figure 1. Typical Pumping Track
Ballast Completely Fouled

Figure 2. Side View of Mud Migrated Into Ballast

MEMBRANE TYPES

Before geotextiles were known, two types of membrane were tested. One, a 0.45 mm (18 mil) impervious PVC plastic sheet, and the other a 2.54 cm (1 inch) pervious fiberglass blanket compressed and semi-bonded to about 10 mm (3/8 inch) thickness. These membranes were installed in tunnels, under turnouts and in roadway crossings with the materials being overlayed or doubled in thickness under high pressure areas such as under track structures in tunnels and under the heel and the frog of switches. The results were that the PVC plastic sheet failed rapidly due to the fact that the impervious membrane prevented the escape of capillary water, and high pore pressures developed resulting in plastic flows in subgrade material. The pervious fiberglass blanket resulted in excellent track surface without maintenance because pore pressures were dissipated rapidly through the fiberglass blanket.

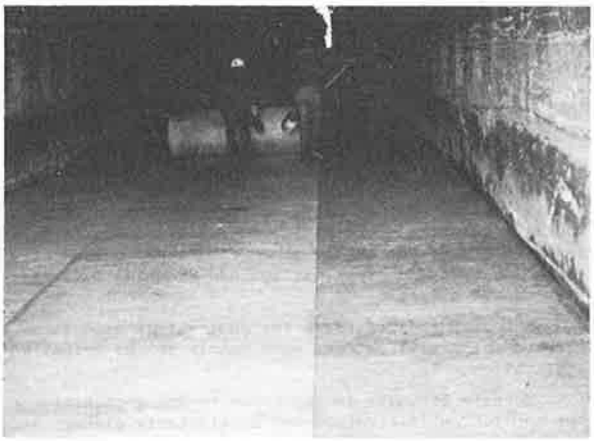

Figure 3. Fiberglass Mat in Tunnel With Double
Thickness Under Track Structure

POLYMER GEOTEXTILES

Our company first started testing various types of non-woven geotextiles in south Texas where long periods of heavy rainfall occur and some of our lowest shear-strength, high plastic, expansive clay subgrades exist.

Geotextiles tested have consisted of either polyester or polypropylene polymer fibers with one having nylon added to polypropylene fibers. Short staple, long staple, and continuous filaments were tested, and the fineness of the fibers have ranged from 0.44 to 1.0 tex (4 to 9 denier). Geotextiles which have been bonded by needle punching, heat bonding, or combinations thereof, have been tested. Weights tested have ranged from 140 to 1400 g/m^2 (4 to 40 oz/yd^2). Woven geotextiles have not been used for reasons that will be explained later.

CALDWELL, TEXAS, TEST SITE

As previously mentioned, the test site at Caldwell, Texas was extensively instrumented. The subgrade consisted of expansive plastic clays and various geotextiles were installed under the ballast in the different sections. The instrumentation consisted of gauges, sensors and meters for measurement from the ball of the rail into the subgrade. As trains travelled through the various sections, these instruments measured rail bending, tie-plate load, cross tie strains, ballast deformation, earth pressure, subgrade deformation, soil moisture, pore pressure, soil expansion, and system dynamic responses. All of this data was fed into a computer where it was stored for analysis. In addition to the instrumentation, alignment and surface track surveys, soil sampling and visual inspection of geotextiles were made. A detailed report on the instrumentations and the test sections was published in American Railroad Engineering Associated Bulletin 678,June-

July 1980, page 361.

INSTALLATION

Geotextiles have been installed under high-speed main tracks, sidings, spurs, etc., and both in rehabilitation of existing track and in construction of new track. Depth of installations have varied from between the ballast and the subgrade with only 15 cms (6 inches) of ballast below base of cross ties to 45 cms (18 inches) below subballast in addition to the ballast. Needle punched geotextiles have been installed under main tracks and, in particular, under switches in two layers with double thickness located under the main track structure. Installations have been in all types of terrain including swamps and mountains, and subgrade soils have varied from very expansive plastic, low strength clays to high strength sand and gravels containing excessive fines.

SUBGRADE PREPARATION

Railroad subgrades were orginally constructed with local native materials without knowledge of soil compaction. These subgrades became compacted over the years by traffic tamping and became somewhat stabilized under light weights and low speed traffic. The maintenance of surfacing and alignment was accomplished by large gangs adding additional ballast. The increase in traffic loads and speeds in the United States during recent years have intensified subgrade stability problems. That is, these heavier loads and greater impacts have increased the stress in the subgrade to a greater depth than was previously stabilized.

When subgrade stabilization of existing, old track is to be performed, consideration is given to the prior stabilization and the addition of only a geotextile under rehabilitated ballast may suffice. If only geotextile is installed for stabilization, some spot failures can be expected due to local subgrade conditions, but these can be avoided by spot stabilization work before or during rehabilitation of track if the spots can be determined ahead of time.

A subballast should be installed on top of the geotextile when geotextile alone will not be ample to provide stabilization. The subballast should be high in shear strength and free draining, but does not necessarily need to be well graded. Depth of subballast required depends on subgrade shear strength, drainage, etc., but 15 to 20 cms (6 to 8 inches) is ample depth in most old existing roadbeds. Very often track structures cannot be raised in elevation to accommodate the addition of subballast or additional ballast due to overhead clearances, roadway crossings, switches., etc. Subgrades can now be lowered to a depth permitting these additions by using modern track plows or track undercutters. It is not possible to obtain a subgrade crown when using a track undercutter, and to eliminate a major negative crown it is necessary to keep the chain on the undercutter taut.

In new construction, the top 20 to 30 cms (8 to 12 inches) of the subgrade is compacted to 95 percent of optimum density. Often, in heavy rainfall areas, a drying agent such as lime or flyash is mixed with the subgrade soils to expedite construction in obtaining the required compaction. After compaction is completed the surface of the subgrade is made reasonably smooth by blade if necessary, and the geotextile is installed as taut as possible with center of geotextile on center line of subgrade. A selected subballast is then placed on top of the geotextile. If the subgrade materials have high shear strength, but contain excessive fine soils that allows 'pumping', only a geotextile providing filtration and separation is required without any subballast.

In all subgrade stabilization work, good drainage should always be provided. This drainage may require the installation of subdrains as well as surface drains.

METHOD OF INSTALLATION

In rehabilitation of track structures, installations have been made by removing the track, and after removal of the fouled ballast, the geotextile installed by unrolling by hand. When a ballast plow is used, it has been installed both directly behind the plow or by a sled after being plowed. The sled can be pulled by a track crane or other similar equipment at a very fast rate. When a ballast undercutter is used, the installation of geotextiles may be accomplished by using a sled, by unrolling geotextiles by hand parallel and near to the track and the track raised with jacks and the materialis then pulled side ways onto the subgrade. Another method used is to raise track with rail tongs attached to a spreader bar and lifted by track crane. In this case, a roll of geotextile can be placed under track structure and unrolled by hand as

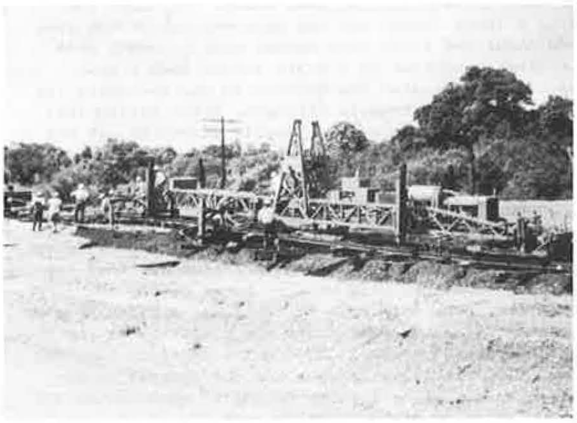

Figure 4. Track Plow Removing Fouled Ballast and Lowering Subgrade

Figure 5. Geotextile Inserted Behind Sled

the crane moves progressively along the track.

In new construction, geotextiles are either unrolled by hand or by equipment. When using the equipment method, a pipe is placed through the center of the roll and each end attached by a chain to mobile rubber-tired equipment. One end is anchored, and the geotextile unrolls as the equipment moves down center of subgrade. The equipment method is very fast and geotextiles can be kept in tension. In all installations, the ends of each roll should be overlapped at least two feet or should be sewed together.

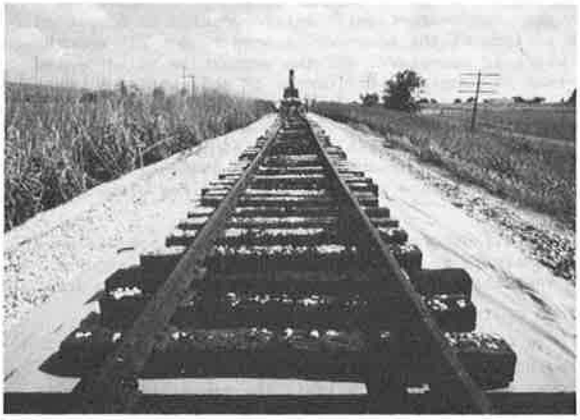

Figure 6 Track Structure on Seotextile After Insertion Behind Track Sled

Subgrade stabilization under turnouts, tracks down streets, roadcrossings and unstable spots are usually performed by removal of the track, and geotextiles are installed in almost all of these locations by hand procedures. A double thickness or heavy weight geotextile is always installed under the high pressure areas even when a subballast is added.

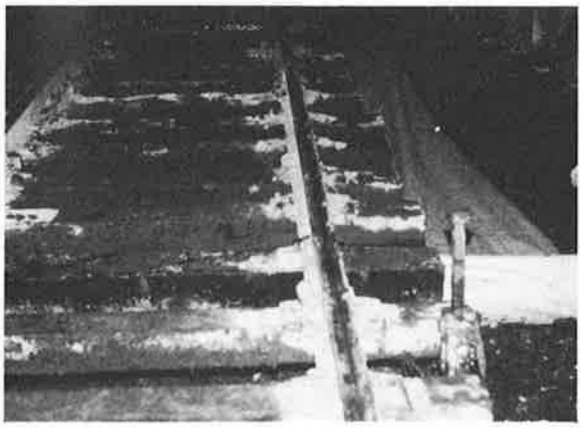

Figure 7. Geotextile Installed by Raising Track with Jacks.

If the geotextile is installed on subgrade without removal of track structure, subballast and ballast may be installed by common method from railroad ballast cars. Tamping of subballast or ballast should not be performed until at least 15 cms (6 inches) is under the base of the cross ties, and then only if the tamping feet are adjusted to prevent driving the ballast through the geotextiles. This is particularly true where lateral ballast resistance occurs such as the side next to another track, group tracks in yards,etc. Full depth tamping will not affect geotextiles if depth of cover below the cross ties is 30 cms (12 inches) or more.

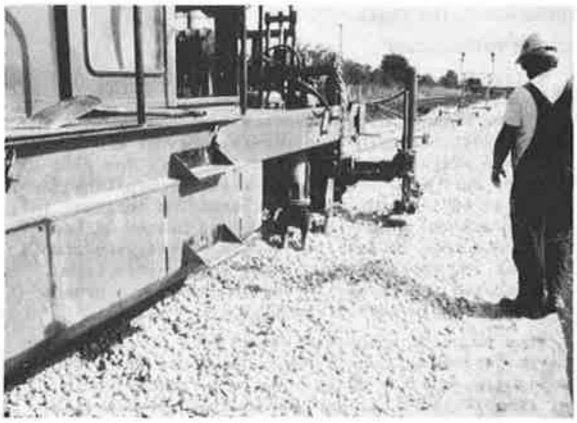

Figure 8. Ballast Tamper Compacting Ballast with Tamper Feet Being Closely Observed for Geotextile Damage.

STABILIZATION FUNCTIONS OF GEOTEXTILE

When I first started using geotextile membranes on railroad subgrade, it was believed that the membrane would only function as a filter and a separator between the ballast and the subgrade. It was soon realized that tensile strength of the geotextile was also contributing to the subgrade stabilization. Tensile stresses are well known to develop when a high modular ballast rests on a low modular subgrade. When ballast was removed from the test sections, the geotextiles were sometimes in high tension even though they were installed in a loose state, and the deformations of the subgrade under the rails were spread over a larger area than normal, similar to a plate rather than a bowl shape. This indicated the geotextile was spreading the load by providing tensile strength. After giving full consideration to geotextile tensile strengths, it was determined that additional stabilization benefits are being provided.

Subgrades were noted to be moist on the outer edge of the ballast where thick needle punched fabrics were installed and dry where heat bonded fabrics were installed. The conclusion reached at that time was that the thicker geotextiles were wicking water out of the deformations under each rail by capillary action. Removal of excess water would increase the stability of the subgrade, but there seems to be greater benefits than the increase in tensile strengths and the removal of excessive water. After further period of observation and study, I came to the conclusion that the rapid dissipation of high pore pressures in the subgrade through the geotextiles was one of the greatest benefits.

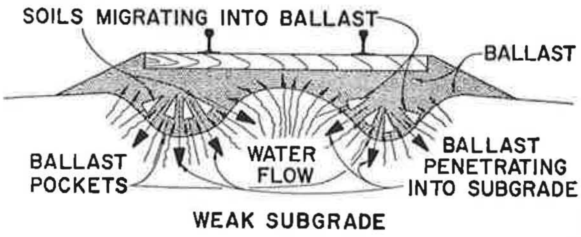

FIG. 9 TYPICAL SECTION WITHOUT GEOTEXTILE

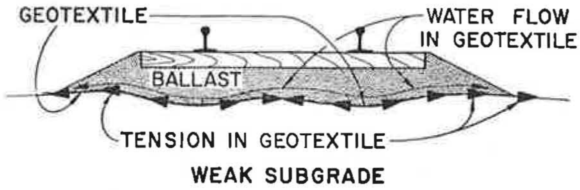

FIG. 10 TYPICAL SECTION WITH GEOTEXTILE

Observations revealed cyclic train loads would further compress the geotextile beyond the compression caused by weight of track structure and squeeze out the excessive water toward the outer shoulder where little or no load is applied. This resulted in fast relief or dampening of the peak of high pore pressures in the subgrade. This function of geotextiles is, in my opinion, very important in addition to their filtration, separation, and tensile strengths.

Figure 11. Mud Swirls From Under Track Indicating High Pore Pressures

Woven or heat bonded geotextiles do not have planar permeability in the material and the top surface of this geotextile will become sealed in a relatively short time. This seal consists of crusher rock dust, locomotive sand, wind deposited dust, traffic car dust, dust from abrasion of rock ballast being washed downward through the ballast onto the geotextile by rainwater.

CRITERIA OF GEOTEXTILES IN RAILROAD SUBGRADE

In addition to their functions, geotextiles should meet certain criteria, as follows:

1. A minimum of 60 percent to a miximum of 100 percent of initial elongation to reduce the possibility of puncture by sharp ballast rock and tearing by ballast tampers.
2. Resistance to ultraviolet ray deterioration.
3. Resistance to clogging by fine soils.
4. Control of void openings under loaded conditions.
5. Minimum creep after initial elongation to provide continuous strength.
6. Provide friction between subgrade and ballast.
7. Resistance to abrasion and tear.
8. In some cases, resistance to oils, chemicals and to heat.
9. Flexibility for ease of installation.

SOUTHERN PACIFIC GEOTEXTILE SPECIFICATIONS AND REASONS

After several years of experience on the use of geotextiles, our company's present specifications for the material is "geotextile fabrics shall be engineering grade, non-woven needle punched comprised of gray-colored polyester fibers having a minimum denier of 1.0 mg/m (9) per filament, a minimum fiber length of 15 cm (6 inches), a minimum fiber tensile strength (tenacity) of 4 grams per denier, and shall be packaged in a minimum 200 um (8 mil) black polyethylene film". Weights and widths are specified for each application, but not less than 4 m (13½ feet) in width.

Some of the principal reasons for these specifications are as follows:

1. Non-woven: Because woven geotextiles do not have planar permeability, and it is anticipated that voids would open under tensile stress resulting in penetration of fine soils.
2. Needle punched: Because heat bonded geotextiles do not provide planar permeability and will trap water just under the geotextile resulting in less stability.
3. Gray colored: The darker shade reduces ultraviolet ray degradation effects and reduces the snow blinding effect of white geotextiles.
4. Polyester fibers: Polyester fibers have higher tensile strength, less creep, better diesel fuel resistance, and are less effected by ultraviolet rays than the polypropylene fibers.
5. Filament of 1.0 mg/m (9) denier: High denier filament will provide rapid planar permeability. This is very important in quickly relieving high pore water pressures in the subgrade when railroad loads are applied. An upper limit denier filament should be specified since a very heavy filament would result in loss of filtration and tensile strength, but the upper limit is unknown at this time. We do know that 1.0 mg/m (9) denier will provide filtration, but there may be a small loss in tensile strength compared to a lower denier. Another benefit is that it appears to be less likely to plug with fine soils.
6. Minimum fiber length of 15 cm (6 inches): Equivalent weight geotextiles made with short fibers have less strength and have excessively elongation.

7. Minimum tenacity of fiber to be 4 gms per denier: The high tenacity of the fibers provides more tensile strength at equivalent weight.
8. Packaged in black polyethylene: Aids in prevention of ultraviolet ray degradation during storage.

Weight of geotextile specified depends on the type of subgrade soil, frequency and duration of rainfall, and traffic tonnage. Width specified depends on the depth the geotextile is installed below base of cross ties. For example, if 30 cms (12 inches) of subballast is used plus 20 cms (8 inches) of ballast, we specify a width of 5.2 m (16 feet).

Woven and heat bonded geotextiles are often punctured by sharp ballast due to their stiffness and low elongation. When heavy denier needle punched geotextiles are infiltrated by very fine soils apparently they are being extruded by high pore water pressures. Tensile strength is very important, but of equal or greater importance is the filter, separation and planar permeability. All known needle punched materials provide ample friction between subgrade and ballast, but I have not been able to detect any abrasion of the fabric in our tests. Puncture during installation, or by sharp ballast, is a very serious problem and methods of prevention must always be considered. Geotextiles will aid in keeping subgrade moisture near constant which reduces the shrinkage and swelling of expansive clays.

TESTS OF GEOTEXTILES

It is to be especially noted that test data such as grab tensile, strip tensiles, etc., are not included in our specifications. I do not consider the present ASTM and other standard tests for fabrics to be applicable to geotextiles. New test standards should be developed which will simulate the field conditions in which they are currently being used. A few manufacturers and suppliers have developed some tests which more simulate field conditions, but they have not been adoped as a standard. In any type of test, the geotextile should be completely saturated with water since all geotextiles inspected under field applications were saturated, and it has been noted that water does effect the characteristics of some geotextiles.

MANUFACTURERS OF GEOTEXTILES

Most of the non-woven fabric manufacturers were producing fabrics for other purposes which, in my opinion, were not necessarily the optimum for use as an engineering geotextile. Even the method of needle punch bonding can effect the characteristics of the geotextile such as spacing, size, and number of barbs of the needles. Caution must be taken when any new type of geotextile is developed containing untested filaments, a mixture of filaments, or the addition of additives. Some functions of the geotextile may be improved, but other functions may be lost thereby making the geotextile unsuitable for certain applications. For example, an additive may reduce the planar permeability and certain filaments such as nylon, can have a major strength loss in the presence of water.

Only recently have a few manufacturers started to attempt to produce a geotextile to obtain better stabilization. The main problem was that the fabric expert did not know engineering applications, and the engineer did not know fabric characteristics. However, in working together better geotextiles are beginning to be produced. In fact, there are now companies producing only geotextile fabrics and they are making designs for specific applications. One such application is a package for different sizes of railroad turnouts, or switches, with the thicker geotextile under the high impact pressure points. These extra thicknesses are then needle punched together which no doubt is better than two separate thicknesses. In addition, the packages are being manufactured to fit the shape of various switches which eliminates waste of the geotextile. However, I must say that we have not detected any adverse effects of the two-layer system. Continual improvements in geotextiles can be expected as both the engineer and the fabric producers become more knowledgeable in geotextiles and their uses.

Figure 12. Geotextile Turnout Package Being Installed under switch.