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Protecting railway sub-grade with a reinforced bituminous geomembrane

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ABSTRACT: As part of a continuing effort to improve the reliability and efficiency of key sections of railway, The Burlington Northern and Santa Fe Railway Co. (BNSF) identified several sections of track requiring refurbishment. The problem was found to be related to the softening of the clay subgrade surface from water entering the track substructure. The solution that Engineers at BNSF chose was to treat the upper part of the clay with lime and cover the clay surface with bituminous geomembrane liner system to inhibit water from coming into contact with the surface of the plastic clay.

1 INTRODUCTION

Burlington Northern Santa Fe operates one of the largest rail networks in North America, with approximately 33,500 route miles covering 28 states and two Canadian provinces.

One line located in north-west Nebraska carries over 250,000 tons of coal traffic daily and is a key rail system for delivering coal from mines in Wyoming and Montana. This line had sites that required frequent surfacing. This not only was expensive but also interrupted train traffic.

Ernest T. Selig, Inc. (ETSI) which is a track substructure expert was asked by BNSF to investigate the cause of the problem and work with BNSF to develop a solution. Background on track substructure technology can be found in Selig and Waters, 1994.

2 DESCRIPTION OF THE SITE

The site to be repaired consisted of two track sections approximately 1.6 km and 0.5 km in length.

The original track in this area was constructed in 1996. The track subgrade soil was a natural highly plastic bentonitic clay. It was treated only by mechanical compaction. The clay was then covered with subballast and finished with ballast and concrete sleepers.

Track performance had become degraded over time requiring frequent spot tamping.

Extensive engineering investigations found that the problem was the result of water in contact with the bentonite clay soil causing softening of the clay surface to a toothpaste consistency (Ref. Hyslip and McCarthy). This lubricated the bottom of the subballast. Under the repeated loading from train traffic, the subballast extruded out the sides of the track bed. As a consequence the subballast layer thinned causing the outer rail to settle. In order to improve track performance in the section of track in north-west Nebraska, the clay subgrade required stabilization and protection from further water damage.

3 THE SOLUTION

Based on the geotechnical investigation several potential alternatives were selected: 1) reinforced bituminious geomembrane 2) mixing of lime with clay and recompacting (admixture stabilization) 3) a combination of 1 and 2. Some of the subgrade clay contained sulfate which in the presence of lime and water could develop a tendency for substantial expansion over a period of time from a process known as "sulfate attack". In the location of this clay type, lime treatment of the clay without eliminating contact with water was unsatisfactory. Also, lime treatment could result in the development of flexural cracks in the stabilized clay. Water entering these cracks would result in the formation of the mud under repeated train loading.

In the original construction the subballast layer was extended beyond the ballast slope to serve as an access road for maintenance and inspection vehicles. However, drainage was impeded by this layer so for the reconstructed track the access road was lowered so the access road surface was at the elevation of the geomembrane. Thus water collecting on the geomembrane could drain out of the track much more quickly. The major limitation of this approach was that it required complete removal of the track, subballast and ballast. However, no suitable alternative was defined that did not require track removal.

To eliminate the effects of water on lime-treated sulfate-rich soil, and flexural cracks in the subgrade, BNSF chose to use alternative 3 (Figure 1). Where the clay was stiff, the outer portion of the top of subgrade was stabilized by mixing in lime and compacting. In the center area, if the clay was stiff, the thin layer of toothpaste consistency clay was removed. In the case where the clay was soft to a greater depth, the clay was either lime stabilized or over excavated and replaced with subballast material. The membrane was placed on the prepared surface so that it extended past the center section. This sealed the subballast material from water infiltration and/or prevented the clay surface from coming into contact with water. Then the required thicknesses of subballast and ballast were placed on top of the membrane. The membrane was sloped to provide good drainage out of the track at the level of the top of the access road.

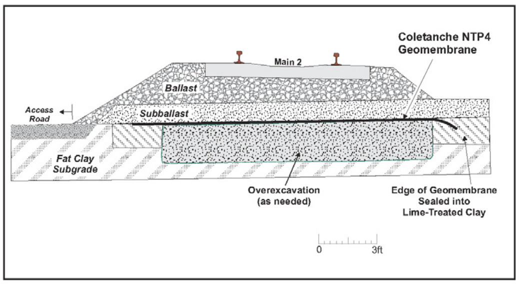

Figure 1: Design Cross Section

The soft clay was removed before adding the lime and the membrane. ETSI had experience with other geomembranes but had never used a bituminous geomembrane before.

Among the reasons for using this particular type of membrane rather than alternative membranes:

- The membrane chosen was substantially thicker
- It has high resistance to puncture
- It has a proven in-service record in railway
- It has good friction characteristics
- It has the potential for installation automation
- It has a high tensile strength

4 GEOMEMBRANE DESCRIPTION

The structure of the geomembrane used is as follows (Figure 2):

- The base of the geomembrane is composed of
  - a nonwoven polyester geotextile whose mass per unit area is 400 grammes per m^2
  - a glass fleece reinforcement which contributes to the strength of the geomembrane and stability during fabrication
  - the whole structure is impregnated with a compound including a blown bitumen of 100/40 pen plus filler
- The underside is coated with a Terphane film bonded when the membrane is hot, and designed to give resistance to penetration from tree roots
- Finally the upper surface is coated with a fine sand to a) provide greater traction on a slope, giving greater operator safety and security from slipping, and b) to give protection from the degrading effects of UV radiation

The sand side was placed against the clay subgrade leaving the Terphane film on the top side in contact with the subballast. This was done to optimize the sliding resistance between the membrane and the substructure layers.

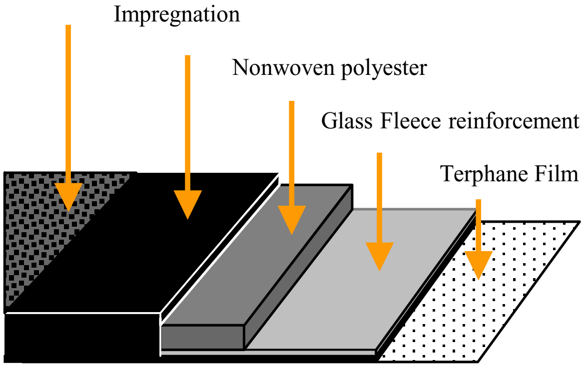

Figure 2: Typical cross-section

The bituminous geomembrane used, Coletanche NTP4, is composed of; a combination of needle punched, non-woven geotextile, glass reinforcement and bituminous impregnation. This system results in a long life expectancy due to it's resistance to high levels of mechanical stress and negligible ageing characteristics.

The manufacturer offers grades of the material appropriate to the end use, in thicknesses from 3.3 mm up to 5.6 mm. This reflects the wide range of uses for this geomembrane, from landfill lining and capping to the protection of groundwater from contamination.

5 EXAMPLES OF INSTALLATION TASKS

5.1 *Preparation of the base*

Preparation of the base involved the removal of the existing ballast, subballast and the very soft clay surface (Figure 3). In areas where the clay was soft, as observed by rutting from the scrapers (Figure 4) the soft material was excavated and replaced with subballast.

Figure 3: Base Preparation

Figure 4: Base Preparation – Soft Area

5.2 *Lime Stabilization*

Lime stabilization (Figure 5) was performed on the outer portions of the subgrade clay when there was over excavation. It was lime stabilized over the entire surface when no over excavation was required to strengthen the clay and prevent the surface softening. The lime would also improve the plasticity characteristics and reduce the swelling and shrinkage potential of the clay subgrade.

the subballast and to prevent water contact with the untreated clay surface. In the case the clay was lime stabilized, the membrane prevented water penetration into any cracks that may develop.

Due to the durability of the geomembrane, it was possible to place the membrane without the use of a separate geotextile protection (Figure 7). This helped to improve the speed of installation, maximized the friction interface with the base, and reduced the overall cost.

Figure 5: Lime Stabilization Equipment

Figure 6 shows the lime stabilized subgrade before final grading and compacting.

Figure 6: Lime Stabilized

5.3 *Placing the Membrane*

Once the subgrade has been prepared and compacted, the bituminous geomembrane is unrolled directly on the base. The membrane had to extend beyond the over excavated area or untreated center zone. This was done to prevent water seepage into

Figure 7: Placing the Membrane

5.4 *Welding of Membrane*

As each roll is completed, the next roll is welded to the previous using a simple yet effective thermal welding process. The simplicity and effectiveness of the welding method for this type of geomembrane liner is a major benefit. The end of each roll of geomembrane is lifted slightly, and a propane gas torch is used to heat and liquefy the bitumen (Figure 8). The two layers of material are then brought together and then rolled with a light hand held roller to produce a continuous seam. The very edge is then heated and toweled over to remove any possibility of failure.

Figure 8: Welding the Membrane

5.5 *Inspection of Welds*

All seams in the geomembrane were tested for defective welds using an ultrasound device (Figure 9). With this it is possible to establish the integrity of all welds with complete confidence. An ultrasound pulse is generated by a transducer, which also detects the reflected signal from the underside of the weld, displaying the readout on a screen as two peaks. Any defects show up as a secondary peak and the area can be marked for remedial action – repair is simple, by cutting, re-welding and then placing a patch over the repair overlapping by 200 mm.

Figure 9: Inspection of Welds

5.6 *Placement of Subballast and Ballast*

Subballast was placed directly on top of the geomembrane without the use of geotextile protection (Figure 10). It would have also been acceptable to place the ballast directly on the geomembrane; however, due to grade requirements for the final track it was less expensive to use subballast. This ability to accept ballast or subballast is unique to a bituminous geomembrane.

The bottom dump trucks first deposited subballast along the edge of the membrane. Then the blades plowed the subballast on top of the membrane to prevent vehicle traffic from causing wrinkles. Next a thin layer of ballast was placed followed by replacing the track panels (Figure 11). The remaining steps were to deposit the additional ballast, raise the track to grade, and tamp the ballast.

Figure 10: Sub-Ballast Placement

Figure 11: Replacement of Track

6 RESULTS

The reconstructed track has been in place for 6 months (as of April 2002) and has been performing very well. Follow-up investigations are planned for early summer 2002. This example of waterproofing a railway subgrade demonstrates the successful use of a bituminous geomembrane in a demanding situation.

7 ACKNOWLEDGEMENTS

For over 30 years Professor Ernest T. Selig and colleagues have been leading the development of improved technology for the design, construction, and maintenance of railway track substructure (ballast, subballast, subgrade). The business objective of Ernest T. Selig, Inc. is to help the railroad industry put this technology into practice with optimal use of financial resources.

BNSF is one of the premier railroads of North America and is continually striving to improve their infrastructure in effective and economical ways. The authors would like to thank Robert Boileau and Steve Heidzig of BNSF for their support of this project and commend them for their acceptance of innovative approaches to improving the track structure.

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