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More than 20 years of experience in using a bituminous geomembrane beneath French railway ballast

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ABSTRACT: The paper reviews the use of bituminous geomembranes in French railway engineering over the last twenty years to protect water-sensitive subgrades, and the tests leading to the selection of this type of membrane. It also describes current trends in bituminous geomembrane use for appurtenant works to permanent way.

1. PERMANENT WAY

Moving trains apply dynamic loads and vibrations which cause wear in the rails and sleepers, and deformation and ageing of the ballast, top course and subgrade. Packing, with addition of new ballast as required, and eventual replacement of the ballast, are mechanised jobs restoring track to good condition.

On old lines, frequently built more than a century ago, there may be distress in clay formations with defective drainage. The water softens the clay so that it rises up to reach the ballast under the ratcheting effect of moving trains. "Muddy stains" of this sort appear frequently when there is a change in traffic patterns (increased loads or high speeds).

Railway engineers have always sought ways of preventing this by inserting imported material between the formation and the ballast. The material used might be tamped earth, slag or more recently sand, gravel, crushed stone, etc. according to what is locally available. If it is thick enough and properly placed, this material provides long-term integrity of the track. To prevent upward migration of fines, impregnated fabric of the type used for truck tarpaulins has sometimes been used with layers of sand and lime. This was found to be effective in protecting the formation against water falling on the track. But where the water table was close to the surface, this cure quickly showed itself to be worse than the disease, since water trapped under the tarpaulin robbed the formation of all bearing capacity. In less than two or three years, the condition of the track was just as bad as before the repairs.

Research in the seventies associated with plans for higher train speeds, and analysis of track inspections on operational lines culminated in standard designs for ballast and top course thicknesses and specifications for granular materials [1] to control these processes.

The standard track permanent way is as shown in figure 1.

The material in the foundation courses, and their respective thicknesses, contribute to track performance. These courses consist of the ballast and base course, which may be a single-layer or multilayer system.

Foundation course thickness is governed by (i) the properties of the subgrade, (ii) local weather conditions, (iii) traffic characteristics, and (iv) track (rails and sleepers). The structure illustrated in figure 1 is designed to meet the following criteria:

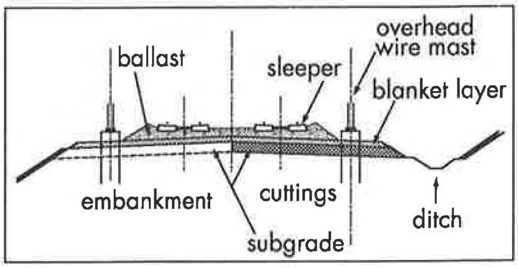

Figure 1 : typical cross-section

Water-shedding performance: Damage to the foundation courses and formation is governed by water content, i.e. water-shedding performance. With an adequate cross fall (3-5%) on the gravel top course, proper grain size and energetic compaction, four-fifths of rainfall runs off at the ballast/top course interface directly into the side ditch, the remainder infiltrates into the top course.
Anti-contamination: Soil fines may migrate upward into the ballast under the effect of water and traffic. Fines may be produced by attrition of the ballast or top course, or come from the formation level, if it is cohesive soil. This process was studied by French Rail SNCF and IRIGM, Grenoble, and a paper is being presented to this Congress [2].
Bearing capacity: On the basis of in situ observations, full-size model tests and mathematical modelling, foundation structures have been designed to suit different subgrade and base course types. Thickness of the structure in relation to the various parameters are given in specification UIC 719R [3].

All these conditions have been sufficiently studied to ensure that the proposed structures are reliable and maintain track integrity. However, they have the drawback of being very thick.

2. BALLASTED TRACK WITH REINFORCED BITUMINOUS GEOMEMBRANE

With water-sensitive soils (clays) and soft or weatherable rock, a reduction in the thickness of the foundation courses can be obtained by using a geomembrane, so that the formation is protected against water and the subgrade can be considered as moving up one category.

Where there is still or flowing water in the foundation soil, of course, particular care is needed in lowering the water table sufficiently and collecting the drainage to prevent it being trapped under the geomembrane and saturating the subgrade.

When building new track, it is wise to provide a drain course under the geomembrane, in addition to the water-lowering works (fig. 2a).

For local repairs to old track (fig. 2b) by this method, it is not usually possible to add a drain course and the geomembrane alternative can only be considered if the hydraulic and hydrogeological conditions at the site are judged good, i.e. when the formation is adequately drained and the water table lies at sufficient depth under the foundation structure.

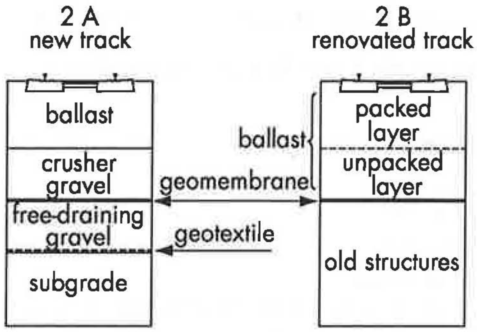

Figure 2: Foundation Structures using Geomembrane

The SNCF criterion of the water table not being less than 2m below the ballast offers a sufficient margin of safety. It can be reduced to 1m below the top course if the water table is lowered by an effective, well-maintained drainage system. Stripping must be kept to a minimum to retain the pre-existing structures. The work must be conducted in such a way as to avoid damaging the geomembrane when jacking and packing the sleepers by mechanised means; this involves placing a loose, unpacked course before re-laying the rails.

The geomembrane solves the contamination problem more easily than using several intermediate course of carefully-graded granular material. This structure is therefore ideal where the formation contains a high proportion of fines or consists of soluble rock.

3. TESTS

In response to these problems, SNCF made full-scale tests on several different membrane types using the Vibrogir apparatus, which applies cyclic loading to simulate the passage of axles over the sleepers.

Under half the sleeper, the ballast sits directly on clay. Under the other half, a geomembrane is inserted. After several hours' operation, it is found that the clay moves upwards into the ballast where there is no geomembrane, and thoroughly contaminates it. Geomembranes are tested in this way to withstand, without damage, more traffic than would occur in twenty years on the most heavily frequented lines.

Geomembranes react differently to these loads. Many are punctured and leak, others deform and

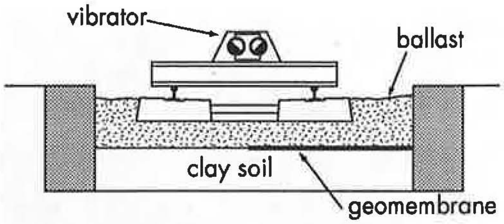

Figure 3: Vibrogir

sag, forming a depression where rainwater collects. The best results are obtained by reinforced bituminous geomembranes more than 5mm thick, which have the advantage that they can accommodate sharp stones from the ballast without ceasing to be watertight. These stones become embedded in the bitumen. This produces a barrier formed from the membrane and entrapped stone particles that preserves the watertightness of the structure under dynamic loads and provides a good bond between the various parts, due to the high surface friction.

While the track tests were proceeding, a puncture test was developed. In this now-standardised test {4}, a specimen of geomembrane is subjected to puncturing by 10-20mm aggregate simulating the ballast. The test determines the maximum load that can be applied to the aggregate without the geomembrane starting to leak. The leakage criterion is verified by applying slight air pressure under the membrane. In this test, the particles embedded in the geomembrane remain part of it so long as it does not leak. The binding of aggregate to the geomembrane in this way is characteristic of the behaviour of bituminous geomembranes (photo 1).

The advantage is this procedure is that it tests the combined material formed by the bituminous geomembrane plus aggregate. It can be used also for other complex materials.

4. HISTORY OF COLETANCHE GEOMEMBRANES USED ON RAILWAY FORMATIONS

The first application dates from 1973, when the geomembrane was produced in situ. Shell Mexphalte 100/40 blown bitumen was spread on geotextile at a rate of 10kg per square metre. The 40,000 m² of geomembrane produced in this way was separated from the ballast by a layer of gravel.

In the same year, the technique was applied at another job at Chennevières near Paris. The geomembrane was again fabricated in situ, in 9m by

photo 1 10-20mm Aggregate Embedded in Bituminous Geomembrane

2m sheets, which enabled the bitumen content to be reduced without adversely affecting performance. This was the first step towards factory-produced geomembrane, which appeared in 1974, in the form of 55m rolls, 4m wide.

This new product was used near Limoges to keep rainwater off a weathered granite bedrock in a deep tunnel portal cut. The geomembrane was placed directly on the stripped surface and covered with ballast. SNCF considered this job as a test bed for the technique and the geomembrane was inspected regularly. It is still performing satisfactorily after twenty years.

These encouraging results prompted SNCF to use Coletanche on a regular basis for its track maintenance, the 4m x 4m sheets being slipped under the track after stripping the old ballast, and seamed by blowtorch. The new ballast is then placed directly on the geomembrane (Photo 2, 3).

Over the last fifteen years, annual consumption has fluctuated between 10,000 m² and 20,000 m² for existing track improvements. For new track construction, 60,000 m² of bituminous geomembrane has been used in renovating the track layout at Gare du Nord station in Paris, to guard against rainwater infiltration in the gypsum-bearing subgrade. For this job, the geomembrane was dispensed from the roll directly onto the formation and seamed at drains.

Today, new uses for bituminous geomembranes are emerging:

- To waterproof earth ditches in inaccessible locations, by reason of the ease with which this product is transported and laid (photo 4).

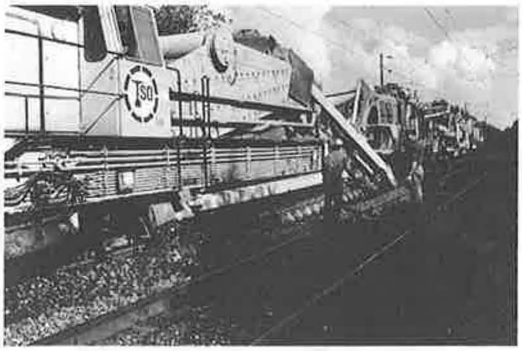

Photo 2: Track Maintenance Machine

Photo 4: Lining Inaccessible Ditch with Bituminous Geomembrane

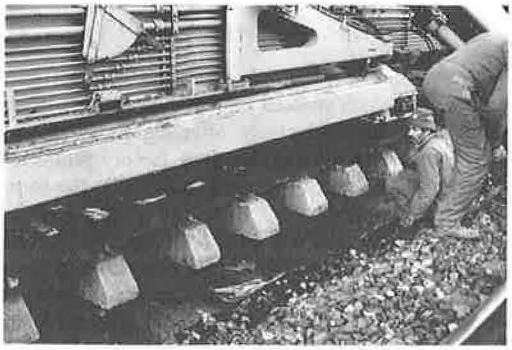

Photo 3: Placing Geomembrane Panels

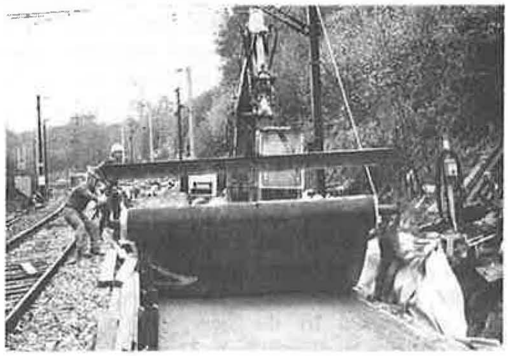

Photo 5: Unwinding Geomembrane from Roll for New Track

- To keep the working area dry against groundwater seepage when building new works (photo 5).
- To line tanker truck spillage bunds. The surface was treated against kerosene attack although the bund was scheduled to be drained within less than three days for safety reasons.

5. CONCLUSION

Changes in railway engineering have lead to precise specifications for the foundation structures needed for ensuring good track performance, preventing upward migration of fines and protecting the formation against seepage. The use of bituminous geomembranes over the last twenty years has made it possible to build permanent way that has given complete satisfaction in solving specific problems associated with sensitive soils and difficult working conditions. Success has only been achieved by observing specified conditions of use, such as the position of the geomembrane with respect to the water table. Tests currently in progress will enable the use of bituminous geomembranes to be extended to appurtenant railway works.

REFERENCES

[1] SNCF. Spécification Technique S.T.590B (Specification for supply of aggregate for permanent way construction and repair)

[2] Imbert, B. & Faure, Y.H. 1996. Use of Geotextiles to Prevent Fine Material from Polluting Railway Subgrades. *Euro Geo 1*

[3] Fiche U.I.C. 719R Structure d'Assise et Ouvrages en Terre des Lignes Nouvelles

[4] Norme Expérimentale P 84/510. Détermination de la Résistance au Percement par Granulats sur Support Rigide