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Bituminous geomembranes used for waterproofing in various transport applications

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ABSTRACT: Bitumen is a natural product, in which its use for waterproofing dates back to ancient times. A bituminous geomembrane (BGM) is manufactured by impregnating a polyester geotextile with an elastomeric bitumen compound. The geotextile provides a high mechanical resistance, while the bitumen provides the waterproofing properties and ensures longevity of the framework by protecting the geotextile. The durability of a BGM is measured in terms of how its key components, their mechanical and low permeable properties are subject to biodegradation by bacteria in various buried applications. Some example project applications in the domain of transportation will be described to illustrate these advantages where the bearing capacity of subgrades of over-consolidated soils can be improved by waterproofing unstable foundations in the presence of water. The infrastructure of the main tarmac runway at St. Georges airport in Utah and a railway track in Nebraska, both in USA will be described.

1 INTRODUCTION

Bitumen is a dense, highly viscous, petroleum-based hydrocarbon that is found in deposits such as oil sands and pitch lakes or it is obtained as a residue of the distillation of crude oil (refined bitumen). This natural substance has been used by humans for a wide variety of tasks and tools for at least the past 40,000 years. It was used in Mesopotamia, 5,000 years ago, to waterproof canals, Babylon gardens, etc. (Schwartz & Hollander 2005).

The first application of an in-situ BGM in transport construction was done to construct aprons for airplanes on low bearing soils, to cover radioactive waste in Texas, USA and a reservoir in the Alps realized with JP. Giroud in 1974.

The first fabrication of BGM in a factory was in France in 1975. This evolution was essentially driven by the need for the ability to control the quality of the product and to have better independence from the weather conditions.

2 BGM STRUCTURE

Bituminous Geomembranes (BGM) have a composite structure consisting mainly of a non-woven polyester long fiber geotextile, impregnated by a compound with a certain mass of elastomeric bitumen (Figure 1). The geotextile provides resistance and bitumen provides watertightness. Every roll manufactured is tested following CEN and ASTM standards for thickness, unit mass, resistance to tearing, static puncture, tensile strength, and elongation.

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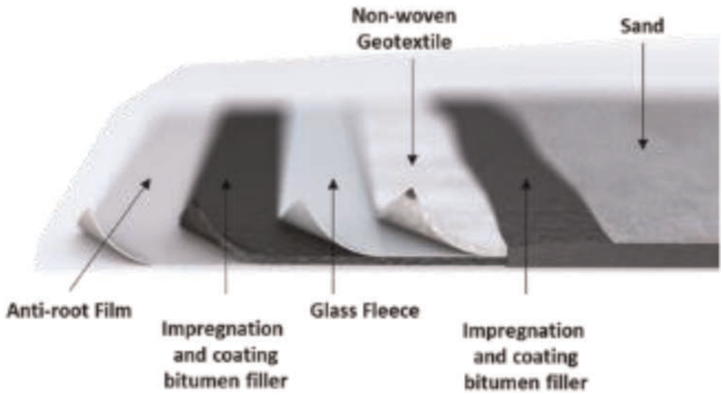

Figure 1. BGM structure.

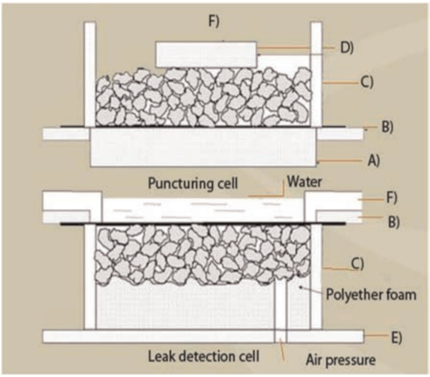

Figure 2a. Apparatus for the test

Figure 2b. BGM after test with aggregates

2.1 *Reasons to use a geomembrane in transport construction application*

The first reason is for waterproofing. Permeability for BGM following ASTM E96 is 6. 10^{-14} m/s. The second reason is for resistance to aggregates puncture (Figure 2a and 2b). Static puncture for BGM following ASTM D4833 ranges from 3.9 kN to 4 kN, while puncture by aggregates following NFP 84-510 ranges from 20 kN to 40 kN.

The third reason is to have a low thermal expansion coefficient to avoid wrinkles during temperature variations. This allows for welding and placing cover materials can be done any time of day with fluctuating temperatures. BGM's low thermal expansion coefficient following ASTM D 696-08 is 0.22. 10^{-2} mm/m/°C, so it remains flat.

3 CASE STUDIES IN TRANSPORT APPLICATIONS

3.1 *Airport, runway reconstruction at the St. George Airport in Utah (USA)*

When the Saint George regional airport in Utah first opened in 2011, it was said the runway would last 20 years, but it only lasted 8 years due to the presence of blue clay under the runway and heavy rains. The runway needed a watertight barrier above the blue clay to avoid contact with water with this soil. This would help maintain the physical and

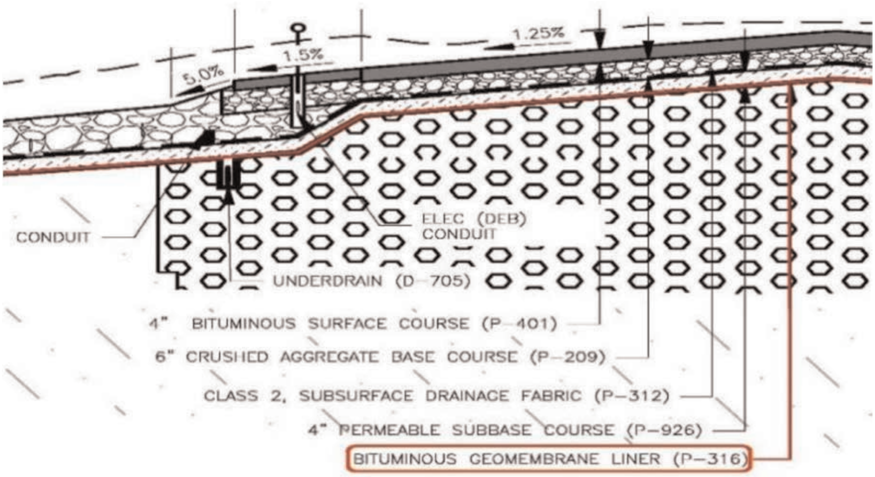

Figure 3. Cross-section adopted for the reconstruction under the layer of asphalt concrete.

mechanical properties of the runway during varying weather conditions. The consultant had selected to use a BGM liner of 4.8 mm of thickness following ASTM D 5199, in order to accept gravel with high grain size and asphalt (temperature of application: 140°C) to be applied directly on top. See Figure 3 for design cross section.

BGM acted like an umbrella covering the blue clay with a wide overhang to avoid any water getting in contact with the structure supporting the runway. Only 130 calendar days were required to complete the entire project (Figure 4a). Figure 4b shows the large grain size of aggregates directly levelled above the BGM. The work was 200 m wide for over 1,600 m long. A team of six workers installed 6,000 m^2 of BGM per day, with an excavator equipped with a special hydraulic beam working 10-hour days in summer (temperature in the shade up to 40°C), for a total amount of 384,000 m^2 of BGM installed over 4 months.

Figure 4a. General view of the site.

Figure 4b. Equipment and material over BGM.

3.2 *Use of BGM in railways construction and maintenance*

BGM is used to protect railway platforms since it prevents clay from contaminating the ballast with water infiltration. The SNCF (French Railways) tested BGM using a in-house test called Vibrogyr (Figure 5), which simulates pulsed loading on the axles of railway sleepers and its foundation. It checks the puncture resistance of BGM with the aggregates on

Figure 5. Vibrogyr testing simulating rail traffic on ballast by SNCF (French Railways).

the ballast. This test showed that BGM could be placed directly on the platform and covered with ballast, without the need of protective layers.

Under half a sleeper, the ballast rests directly on the clay, under the other half, a BGM 5.6 mm thick following standard ASTM 5199 was placed. After estimated testing equivalent to at least 20 years of traffic on the busiest railroad of the S.N.C.F.(Paris-Tours-Bordeaux), it was found that as-is, the clay migrates into the ballast. If there is a BGM protection layer installed, there is no ballast pollution since some ballast aggregates are embedded inside the BGM without piercing the geomembrane. So BGM was used near Limoges, France in 1974, to shelter rainwater and altered granite substratum, to prevent the contamination of the ballast by clay. The construction site was in a deep trench serving as access to a tunnel. The level of the side ditches could not be changed, and it was therefore not possible to put in place thick layers of gravelly materials. It was noted that BGM had a strong resistance to puncture by these materials. BGM was verified after periods of 5 and 10 years till today. It was then found that the stones of the ballast had become embedded into BGM without piercing it, thus confirming the conclusions of the Vibrogyr test (Potvin 2016). The positive results observed on this test section led to the French Railways SNCF to continue the use of BGM on its railway tracks.

This technique therefore allows to save the cost of a deep stripping, followed by the installation of layers of selected materials. In addition, this geomembrane can be set up during a track and ballast renewal operation, which allows the saving of a prior heavy sanitation site.

3.2.1 *High speed european train*

East European High Speed Line (LGV Est) is a French high-speed rail line that connects Paris to Strasbourg, Germany and Luxembourg. During construction, engineers must pass over swelling shale soil near Reims. Shale tends to degrade from a hard rock-like material to a fine-grained soil mass. This degradation occurs over a long period of time, and many engineering problems such as settlements and slope failures are evident only several years after construction. The major difference between shale and clay is the lithification and diagenesis experienced by the shale in contrast to the clay, which is affected only by consolidation process. The lithification and diagenesis process affect geotechnical properties like in-situ void ratio, initial shear modulus, cohesion, apparent pre-consolidation stress, and shear strength (Gutierrez *et al*. 2008). On the other hand, factors that influence the swelling potential are type and amount of clay, initial placement conditions, stress history, nature of pore fluid, and temperature (Nayak & Christensen 1970). The solution found by French railways (SNCF) engineers was to do an umbrella above the shales to avoid any contamination by water by doing a watertight barrier with BGM of 5,6 mm of thickness.

TGV North (Paris-Brussel-Amsterdam-London) crosses a region with the presence of loess and chalk. BGM was used to avoid any diffusion of rainwater and thus avoid any risk of collapse. But this was done only after derailment of a TGV without injury and discovery of caverns under the line already built (Cuiet al. 2008).

3.2.2 *The Burlington Northern and Santa Fe Railway co. (BNSF)*

In Nebraska, the BNSF identified several sections of the existing track requiring refurbishment due to swelling soils (clay). Extensive engineering investigations found that the problem was the result of water in contact with the clay soil causing softening of the clay surface, which lubricated the bottom of the sub ballast. (Hyslip & McCarthy 2000). Under the repeated loading from train traffic, the sub ballast extruded out the sides of the track bed. The sub ballast layer thinned causing the outer rail to settle. In order to improve track performance in the section of track, the clay subgrade required stabilization and protection from further water contact.

Based on the geotechnical investigation, the alternative selected was a BGM of 5.6 mm thick following ASTM D 5199 (Figure 6a). 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.

The existing foundation was removed before adding the lime mixed with secure soil in place and BGM. Sub ballast was placed directly on top of the geomembrane without the use of geotextile protection, which BGM allows without a geotextile layer for protection (Figure 6b) (Selig & Waters 1994).

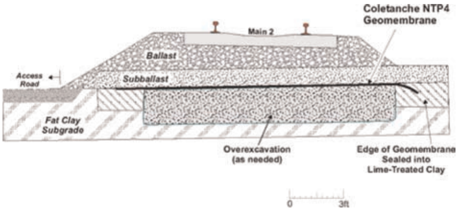

Figure 6a. Designed cross section for BNSF.

Figure 6b. Sub ballast placement directly on BGM.

3.3 *Use of BGM in road construction*

Some projects that will be described are for the application of the European Water Law in road construction. The respect of water quality in Europe is managed within the European Water Framework Directive. There is a directive for Ground water: the Groundwater Directive 2006/118/EC has been developed in response to the requirements of Article 17 of the Water Framework Directive. This includes the protection of the quality of groundwater under roads or highways. Vulnerable areas, fractured soils, and nearby water catchment areas, require waterproofing traffic areas and pavement platform areas, to treat water collected in such watertight basins that separate the water from the light pollutants and heavy elements.

3.3.1 *Protection of potable water on an Aquifer in Switzerland under N16 in Switzerland*
Under the N16 highway, there is the aquifer which supplies potable water for the town of Porrentruy, Switzerland with its 10,000 inhabitants. The fear of the Swiss Ministry of Transport was to have a truck carrying benzine, chemical liquid and having an accident by spilling discharges transported and polluting the ground water. So, they covered the complete exit and a superhighway by BGM to protect the aquifer (Figure 7a and 7b).

Figure 7a. Exit on Swiss motorway N16.

Figure 7b. Exit covered by BGM.

3.3.2 *Sustaining the ecosystem of a pond near a bypass*
In Ireland, a 3.5-km-long section of highway runs below the water table. Authorities wanted to make sure that the highway did not disturb the hydrogeological conditions and ecosystem of a marsh some 5 km from the Kildare bypass. On average, 30,000 vehicles, 20% of which are heavy trucks, pass through Kildare town every day. A 13-km-long bypass should put an end to the long bottlenecks in Kildare. The highway passes in front of one of the most famous racetracks in Ireland. As such, traffic noise would negatively impact breeding, disturb the horses before the races, and bother the spectators.

The solution was to bury the highway surface so that the berm would act as a natural noise-absorbing wall. Because of this, the highway surface was 4.5 m below the water table over a 3.5 km stretch. Of course, it could not pollute the water table nor interfere with the flow of water.

Technical solutions proposed during the call for tenders, and they chose to go with a BGM after a series of tests performed. See Figures 8a and 8b below for BGM installation.

Figure 8a. Membrane installation.

Figure 8b. Membrane over central collector.

4 CONCLUSIONS

The principle in protecting these transport applications is to build an umbrella above water-sensitive soils that avoids clay, gypsum, and inflating shales to be in contact with water. The described examples demonstrate the successful use of a BGM by a proven adequate strength, durability, and low permeability solution over 40 years.

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