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Thick and abrasion resistant geotextile for use under the ballast in railways structure

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ABSTRACT: To extend the life duration of a railway in area where the support structure is damaged or fragile, the use of a thick geotextile between the ballast and the intermediate layer was considered. The functions of this geotextile are to limit the pollution of the ballast by the fine clayey particles of soil, to allow the water flow circulation and the dissipation of the water pressure and to support the total life duration of the refurbishment cycle. Based on North American specifications for similar conditions of use, a geotextile was specially made. To verify the behaviour of this geotextile, an experiment was launched using the "vibrogir", device simulating the solicitations of a railway traffic. It shows that the geotextile keep his characteristics of permeability, normal or in the plane and that his duration life estimated at 25 years with the abrasion test, corresponds to the expected application.

1 INTRODUCTION

1.1 *The context*

The firsts Railways in France were built at the end of the XIXth century and at the beginning of the XXth . Quickly, the whole structure (rails and sleepers) has been isolated from the soil by a foundation layer of sand, stones, broken brick, or coal ashes, which was called "ballast" and that should protect the sleepers against the action of the air, the sun and the rain.

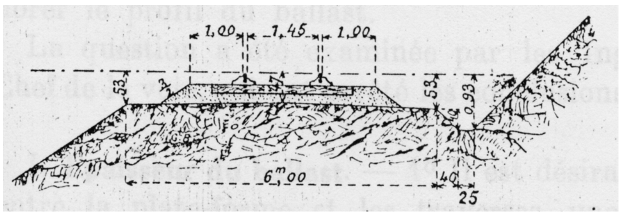

Figure 1 : cross section of a railways - H. SALIN (1925)

With the evolution of the traffic: increase of the circulation number and of the axle load, changes in the constituting materials: rails, sleepers (nature, spacing), the railways were submitted to deformations and therefore rectified in a first step with local materials and finally with more elaborated materials to level up the low points at the height of the high points.

After years of traffic, a layer appeared, called "intermediate layer", more or less thick, constituted with the initial materials polluted by the subsoil, the different elements added to repair the line, all the stuff coming from the train (ashes from the steam locomotive) or elements brought by the wind and the rain. This intermediate layer, generally compact, isolates the current ballast form the subsoil and acts on the old lines as the sub-layer on the new lines.

The nature and the composition of the intermediate layer are often variable. As example the figure 2 shows the grain size range excavated on sandy and clayey subsoil compared to the requirements for the current sub-layer under the ballast. It appears clearly that some intermediate layers do not have the characteristics needed to fulfil correctly the expected functions.

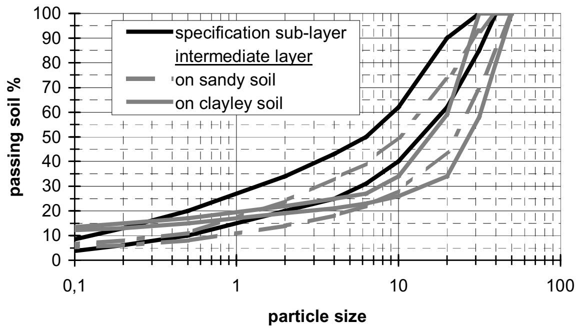

Figure 2 : example of soil for intermediate layers

Following the current concept for the design of railways and with the techniques of maintenance used, the thickness of the ballast under the rails is uniform supposing that the structure under (intermediate layer or subsoil) reacts everywhere identically. Indeed, this is theoretical, but the rules of design and the rules of control are such that the difference of behaviour under neighbour sleepers do not create differential settlement able to disturb the security of the traffic.

It is a need to identify the weak area , the cause of fragility, and to control the degradation, thus allowing the refurbishment works to be scheduled. The follow up of the maintenance work allow to compare the level of damage on a particular section with the average obtained on the lines. The section will be considered as good quality if the refurbishment is lower than the average or as low or very low quality if it is higher. Therefore, a refurbishment seating coefficient may be calculated to characterise the quality of the section.

1.2 *Refurbishment with geotextile of damaged or unstable sections*

In addition to the different techniques allowing to avoid a quick degradation of the structure in difficult soil areas, the use of a thick geotextile placed between the intermediate layer and the ballast has been studied to fulfil several functions.

- The geotextile must limit and delay the pollution of the ballast by the fine particles of clay, in order to maintain the friction characteristics. There the filtration and separation function appear clearly, traducing the hold back of soil particles while allowing the passage of water. The resistance to clogging over long periods under dynamic loading is an important point to be checked.

- The geotextile must facilitate the drainage to avoid the saturation of the intermediate layer that would change the physical state and the mechanical properties of the clayey subsoil, by a plasticise effect.
- The geotextile must also resist to the dynamic loading and the stress of the ballast for the minimum life duration needed to respect the expected date of refurbishment works for the whole railway line.

More currently, the geotextile is placed between the sub-soil and the intermediate layer. The filtration and separation functions remain the same, but the mechanical stress are clearly lower than that in contact with the ballast.

A study was carried out at LIRIGM, FAURE (1996), to evaluate the behaviour of different geotextiles with similar opening size, on fine soil under a dynamic loading. Particularly, using "vibrogir" the same device as describe in the next paragraph, the long term performance of each type of product regarding the filtration function was scrutinized. There the geotextile was placed between the sub-grade and the blanket or intermediate layer. The analysis of the experimentation showed that the needle punched continuous filament performed better than the other types of geotextile. The heat-bonded products were completely clogged and acted as a watertight membrane. The woven materials let the soil go through the ballast and were significantly damaged (cut threads). The non-woven needled punched geotextiles maintained a similar permeability whatever the nature of the subsoil: clay, sandy clay or marl. Then a nonwoven needled punched continuous filament geotextile of 400 g/m2 is able to fulfil all the requirements and is used regularly in the French railways structure.

In this study, if the filtration behaviour of the different type of product was clearly shown, the mechanical stress were not at level of those found in contact of the ballast.

The interest to place the geotextile just under the ballast is to limit the movement of material at the minimum, with the levelling of the blanket layer and the cleaning or the replacement of the ballast. It induces a global reduction of the refurbishment costs.

A general study on railways rehabilitation by Raymond (1999) who has followed some experimentations on geotextile placed under the ballast in North America gave the same conclusion concerning the filtration ability of the different geotextiles. Additionally, he also looked at the mechanical behaviour of the products. The main result is that geotextiles with a weight lower than 500 g/m² are quickly destroyed. Considering the worse situation with fine soils and the effect of freeze/thaw, a specification was written, given the properties of a geotextile placed under the ballast. After years of use, GP Raymond conclude that if the product fulfil this specification and if correctly installed, the behaviour is at the expected satisfying level.

1.3 *Geotextile specification*

A geotextile prototype, based on the specification written by Raymond (1999) in North America has been developed to be tested in the context of the French and European railways. Design methods, materials used and weather conditions are different from North American and the level of stress is not necessarily the same, but the goals are equal: to insure a good filtration-separation system between the ballast and the sub- layer and to survive long time enough to avoid non expected rehabilitation

An extract of these specifications chosen to produce the prototype are following :

- Weight: 1050 g/m²
- Type: Needle punched continuous filament non-woven
- Elongation: 60 %
- Opening size lower than 75 µm
- Fibre bonding by resin treatment or similar with about 20% by weight of low modulus acrylic resin or other material suitable non water soluble resin that leaves the geotextile pliable

2 EXPERIMENTS WITH VIBROGIR

2.1 *Description*

In order to verify the long term performance of the resin impregnated geotextile, the "vibrogir", device studied by the French railways company SNCF to simulate the effects of the traffic on the structure was used.

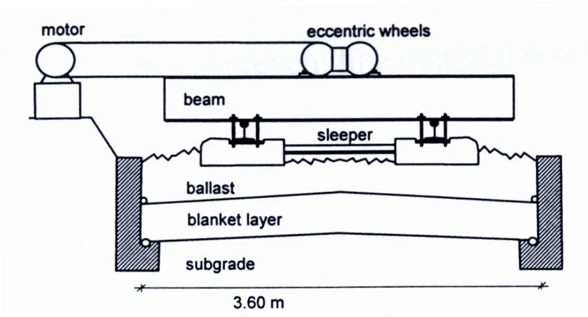

Figure 3 : Schematic cross section through the vibrogir

In the past and for their own purpose, SNCF carried out numerous simulations of railway track sub-grade behaviour under train-induced stresses by mean of vibrogir tests. Some of them were realised with geotextiles (cf §1.2).

A sleeper of a railway track is subjected to 20 tonnes load at a frequency of 50Hz with the use of eccentric wheels. The sleeper lies on a track subgrade at full-scale (see figure 3). It could be considered that a duration of 10 hours of stresses under the vibrogir corresponds to a yearly traffic of 100.000 tonnes per day.

For this experiment, the impregnated geotextile was installed directly between the ballast and the sub-grade, without blanket layer. Therefore, the geotextile was submitted to the most critical stress.

2.2 *Experiment progress*

In order to evaluate the resistance of the geotextile as a function of the time of loading, the experiment was driven in several phases. The area under the sleeper was divided in two parts, respectively the right part and the left part. Each of them had the concrete foot of the sleeper at the centre and therefore submitted to the same stresses.

The geotextile on the left part was removed after 80 hours and replaced by a new virgin sample. The geotextile on the right part was still the same. After a second phase of 120 hours of stresses, the two geotextiles were removed and replaced by virgin material for a last period of 20 hours. For this third phase, the right part was wetted to measure the influence of an higher water content near the surface of the geotextile. At the end of the experiment, geotextiles having submitted to 20 hours (wet and dry), 80 hours, 120 hours and 200 hours were therefore available.

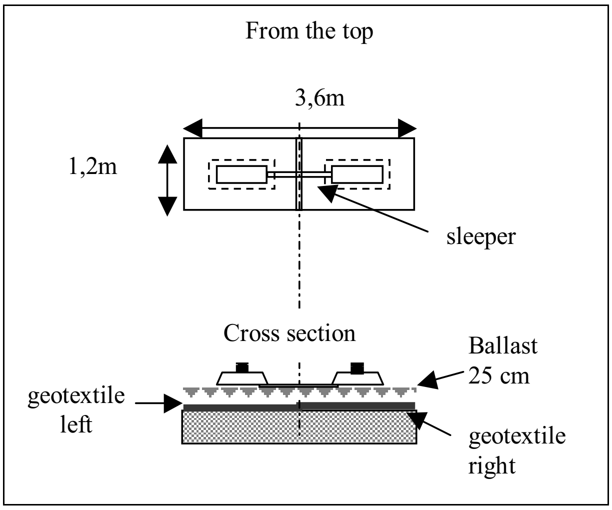

Figure 4 : view of the structure

3 ANALYSIS AND RESULTS OF THE EXPERIMENTS

All the five specimens have been checked visually to see the type of damage if any and their repartitions. After, each of them was submitted to the test relative to mechanical and hydraulic properties.

3.1 *Visual observations*

- Not any hole or tear has been observed on the different extracted specimens.
- The prints made by the ballast were more or less important depending on the duration of the stresses. The geotextile removed after 200 hours was logically more marked than those having stressed during 20 hours at the vibrogir.
- For the geotextiles removed after a long duration (80 hours to 200 hours), a light worn can be observed, traduced by several abrasion marks and some filaments partially dissociated from the layer. But generally, the samples were still in a good condition.
- During the excavation of the geotextiles after the third phase of 20 hours, a larger quantity of fine soil was observed for the wet sample
- The central area of the geotextile is more marked than on the side. This is due to the heavier loading under the concrete foot. Figure 5 shows specimen coming from different areas on the same sample after 200 hours.

Figure 5 : Samples excavated after 200 hours

In the following tests, the specimen were taken out this central area.

3.2 *Measurement on the excavated samples*

For each excavated samples and corresponding for different duration of stress, the changes in the properties were checked.

The mechanical properties have been studied by two tests:

- the pyramid puncture resistance following the French standard NF G 38019. This test should allow to measure the puncture resistance of a geotextile in similar conditions than if it was submitted to the stress of the ballast. The size of the pyramid piston is closed to the size of the stones.
- an abrasion test realised following the standard ASTM D – 3884. The geotextile is submitted to abrasion by a rotative system until his destruction. The number of revolutions reached by the sample constitutes the result of the test.

Figure 6 : Abrasion test device

The hydraulic properties were also measured :

- the water permeability normal to the plane following the standard EN ISO 11058,
- the water flow capacity in the plane following the standard EN ISO 12958

3.3 *Results of the test*

3.3.1 *pyramid puncture NF G 38019*

Excavate samples did not show a lost of puncture resistance but a slight increase compared to the initial resistance. This is certainly due to the particles of soil blocked on the geotextile given more stiffness to the product. Nevertheless, this test cannot be used to evaluate the ageing of the product under the traffic.

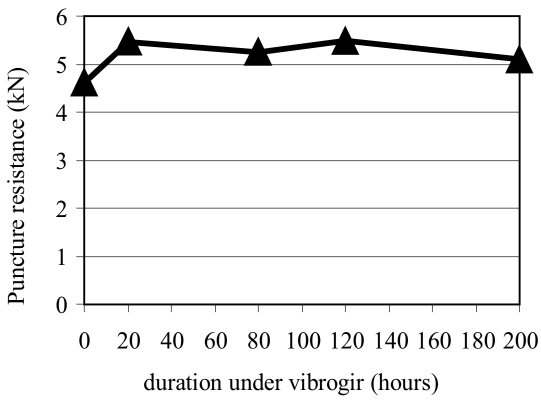

Figure 7 : evolution of puncture resistance – NF G 38019

3.3.2 *abrasion resistance following ASTM D –3884*

Despite a significant variation in the results for the same duration, due to the difficulties of clamping and some modifications of the abrasion conditions during the test, a trend can be noticed. The number of revolutions needed to destroy the geotextile decreases when the duration of loading increases. After 200 hours of loading at the vibrogir, still 2000 revolutions on abrasion test remain necessary to destroy the geotextile prototype.

For this geotextile, we can estimate that a duration of at least 250 hours under the vibrogir could be supported which corresponds to a potential life duration on railways of 25 or 30 years at the minimum.

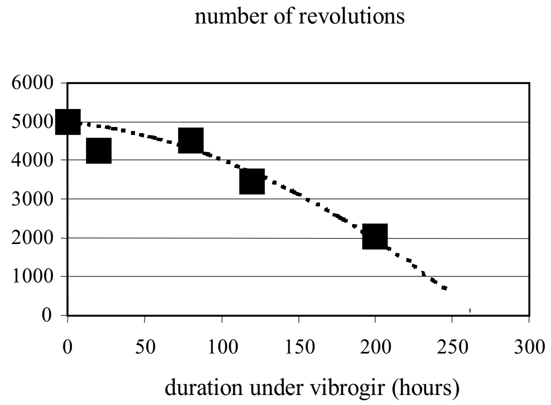

Figure 8: evolution of the abrasion resistance ASTM D-3884

3.3.3 *permeability normal to the plane EN ISO 11058*

The vertical permeability show a slight decrease because of the soil particles in the geotextile. However, the permeability keep at a satisfying level, significantly higher than the minimum needed. No clogging occurred which could affect the behaviour of the structure.

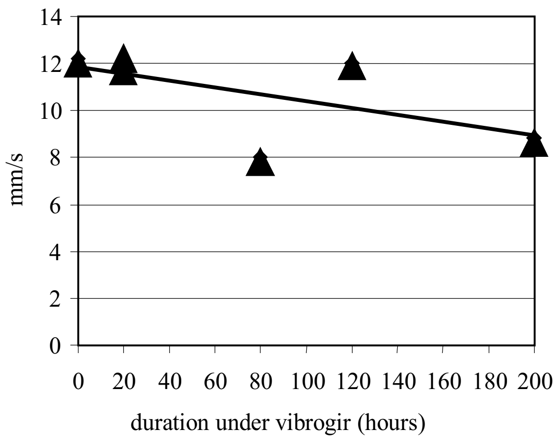

Figure 9 : evolution of permeability EN ISO 11058

3.3.4 *water flow capacity in their plan EN ISO 12958*

The measurements do not show substantial modification of the water flow capacity nor difference of permeability between the dry and the wet sample. The drainage characteristics are not affected by the test.

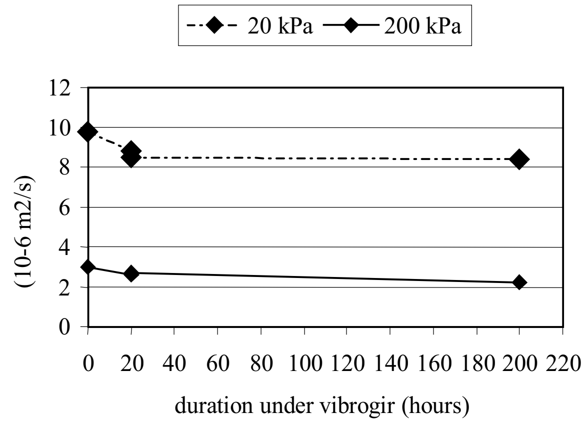

Figure 10 : evolution of the water flow capacity

4 CONCLUSIONS

This experiment was realised to verify the long term behaviour of a specially designed geotextile to support the railway dynamic loading. It shows that the geotextile keep his hydraulic properties, water flow capacity and vertical permeability but also his puncture resistance which was not affected by the simulated traffic. Following the lost of resistance evaluated by the abrasion test, the life duration can be estimated at more than 25 years.

This thick geotextile was made for local maintenance on normal speed lines to extend the life duration of sections where the frequency of the repair should be higher than on the rest of the line. It allows to reach the end of the maintenance cycle which has been planned for the whole line.

Additionally to this study, some experiments in real scale are planned.

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