Geosynthetics: Applications, Design and Construction, De Groot, Den Hoedt & Termaat (eds)
© 1996 Balkema, Rotterdam. ISBN 90 5410 836 3

Use of geotextiles to prevent fine material from polluting railway subgrades

Y.H. Faure
IRIGM University of Grenoble, France

B. Imbert
SNCF Direction de l'Equipement, Paris, France

ABSTRACT :
Various tests were performed with a view to studying the rise of fine muddy material in the blanket layer of railway lines. These tests clearly showed the influence of the compactness of the subsoil. The efficiency of a separating geotextile layer to restrict the amount of rising mud becomes all the greater as the subsoil is less compact and with improved drainage of the structural layers. The influence of the geotextile structure was also studied.

1. INTRODUCTION

1.1 *The problem*

When the first railway lines were built, it was quickly found that fine particles in the ground would rise through the ballast in the form of mud patches. These generally result from :
- deformation and ageing of the various components of the subgrade,
- incorrect assessment of the quality of the subsoil,
- unsatisfactory operation of the drainage system,
leading to destruction of the structures over a varying time scale.

The following measures are therefore necessary in order to prevent this from happening :
- proper sizing of the subgrades,
- laying the subgrades with a suitable slope so that water falling on the track is quickly drained away,
- using good quality materials,
- constructing the subgrade with all due care and attention.

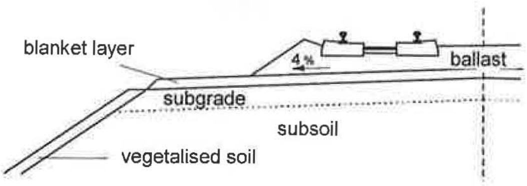

Figure 1 : Schematic cross-section of a railway line structure.

In this way, a structure of the type illustrated in figure 1 can be obtained, where the subgrade can be made either from material brought in or from the subsoil improved by compacting. This study concentrates on this second possibility.

It is relatively easy to respect these rules when new works are involved. However, it is not at all the same case for railway tracks already in service where the subgrades laid have to be accepted for what they are, and where the traffic and the environment are constantly changing. This explains why mud patches continue to be observed along such tracks.

To minimise the amount of mud rising to the surface, the use of a geotextile material may be a simple, easy-to-implement solution that is both low in cost and durable, provided the geotextile chosen has properties suited to the in-situ soil and to the conditions of use.

An experimental study was carried out jointly by IRIGM (University of Grenoble) and French Railways (SNCF, Direction de l'Equipement) to study the mechanisms of rising mud phenomena and to analyse the parameters playing a major role.

1.2 *Study performed*

Work carried out previously (Loubinoux et al., 1982, Faure et al., 1984) showed that, in case of cohesionless granular media subjected to dynamic compacting, the main parameter ensuring soil retention by a geotextile is the grain size. Thus, if the filtration opening size of the geotextile is less than twice the grain diameter, figure 2, a stable granular

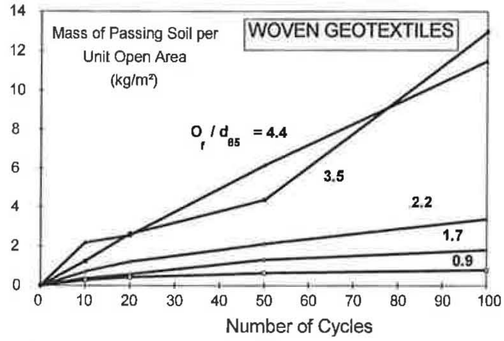

Figure 2 : Effect of filtration opening size on the mass of soil passing, per unit open area, through a monofilament woven geotextile (tPT, cf. §2) in relation to stress cycle. Cohesionless soils with narrow particle size range (Faure et al. 1984).

structure is formed in contact with the filter, even under dynamic stress conditions.

However, for fine coherent soils, the simple comparison of filtration opening size and grain diameter is not sufficient because soil cohesion and compactness play a major role.

Three types of test were performed on clay under different conditions and the following points were considered :

- subsoil made of compact clay : under what conditions do clay particles rise through the blanket layer and is the geotextile efficient ?
- subsoil made of soft clay, to accentuate the phenomenon of rising mud, how do different textile structures work ?
- under real conditions, on a full-scale rig, do results show that the geotextiles behave in a similar way ?

This article presents a summary of the main results obtained.

2. GEOTEXTILES TESTED

Various geotextile structures were tested :

AM : slit tape wovens
PF, BD : needlepunched non-wovens
TP : heatbonded wovens
tPT : monofilament wovens

These geotextiles are characterised by two numbers, for example TP(220,90) :

- the first is the mass per unit area (g/m^2),
- the second is the filtration opening size, noted O_f, determined by hydrodynamic sieving (µm).

3. TESTS ON COMPACTED CLAY

3.1 *Test principle*

A dynamic loading frame, fig. 3, was designed and built using motors with eccentric wheels. This frame can be used periodically to compress a sample up to 200 kPa with a frequency of 25 or 50 Hz. The sample consists of the two following layers representing the blanket layer and the subsoil :

- a layer of 0/20 100% crushed, clean, dark grey basalt gravel, lying on
- a layer of ochre clay (80%>40µm) of class A2 (according to the French NF P 11300 standard classification) representative of a large part of the clayey soils found in France.

These two layers may or may not be separated by a geotextile. The combined thickness of the two layers is about 120 mm on placing. For all the tests, the clay has a degree of saturation greater than 90%. The test duration is 48 hours.

During the test, applied force and movement are continuously measured (fig. 4). At the end of the test, the assembly is dismantled and samples are taken. A water content profile can be drawn up (fig. 5) but the presence of clay in the gravel is easily discernible through the colour difference, so that the height to which the mud rises can be determined visually.

3.2 *Results obtained*

Three series of tests were carried out to highlight the role of clay compactness, geotextiles and gravel saturation.

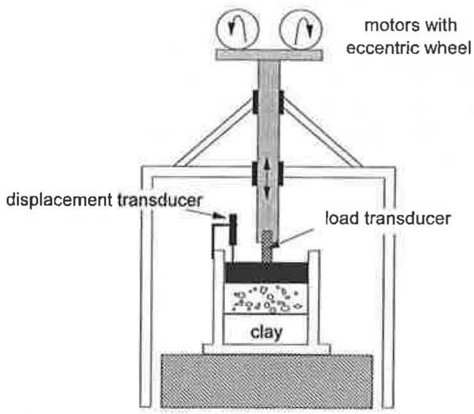

Figure 3 : Diagram of the dynamic loading experimental device.

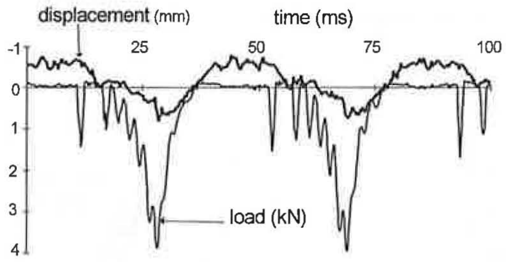

Figure 4 : Example of load and movement variations during the test.

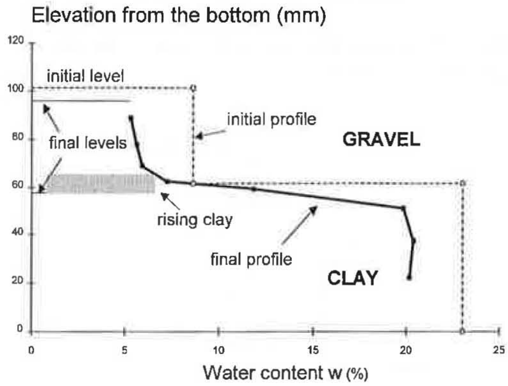

Figure 5 : Example of a water content profile and position of the rising clay level in the gravel.

3.2.1 Moist gravel, without geotextile, influence of clay density.

For this series of tests, the initially dry gravel was lightly moistened (w ≈ 8 to 10%).

The test results are presented on the graph in figure 6. The height to which the clay rises is represented as a function of the clay compactness. The Normal Optimum Proctor value (NOP, $\gamma_d = 17.1$ kN/m^3) is shown on the diagram.

The extent to which mud rises is highly sensitive to the compactness of the clay in the subsoil. It is virtually zero when the clay is very compact, $\gamma_d >$ NOP.

3.2.2 Moist gravel, with geotextile between the two soil layers.

Two types of geotextile were tested :
- a needlepunched geotextile BD(340,90), and
- a heatbonded geotextile TP(280,40).

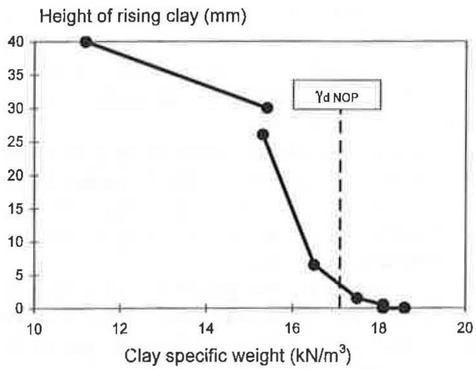

Figure 6 : Influence of clay density on rising clay

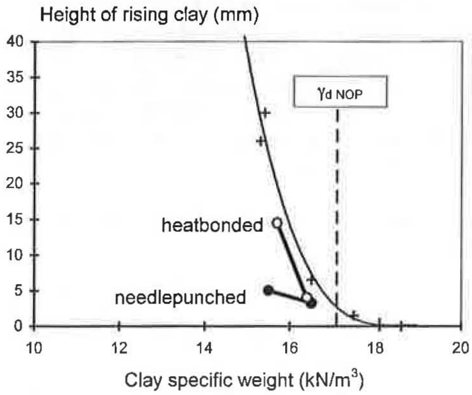

Figure 7 : Geotextile influence on rising clay

As in the previous test, the gravel was lightly moistened before placing (8 to 10% water content). Figure 7 clearly shows the role of the geotextile : it reduces the rise of clay material, all the more so as the clay in the supporting soil is less compact, and better results are obtained with the needlepunched non-woven geotextile.

Observations :
- The clay surface is smooth and uniform under the needlepunched non-woven geotextile whereas outlines of the gravel appear in the clay under the heatbonded non-woven material. The thicker, more compressible structure of the needlepunched non-woven material ensures better distribution of the applied stresses compared to the heatbonded structure.
- The displacement of the finest particles from the clay surface leads to the formation of a fine uniform

layer of sand under the needlepunched non-woven geotextile. For the heatbonded material, the sand accumulates around the gravel imprints and this clearly indicates that initial soil movement occurs especially in the shear zone.

The presence of this fine layer of sand confirms the formation of a « self filter » which promotes clay retention. It also forms a permeable layer allowing better distribution of surface water contents and enhanced bearing capacity.

- Above the geotextile, the gravel base is cemented by the rising fine materials which form a more compact layer above the heatbonded geotextile compared to the needlepunched material.

Geotextile permeability :
When the clay is not very compact, the permittivity of the geotextile does not change significantly, regardless of its nature ; on the other hand, when the subsoil is compact the permittivity of the needlepunched geotextile hardly changes at all whereas that of the heatbonded material is ten times lower. This behaviour is similar to that found during Vibrogir tests (cf. § 5).

3.2.3 Saturated gravel, with or without geotextile.

For this third series of tests, the gravel was saturated after placing over a thickness of about 20 mm. The aim was to simulate faulty operation of the drainage system or a « counter slope » preventing the water from draining away.

When the blanket layer (represented by gravel in this case) is saturated, and even if the subsoil is suitably compacted, considerable amounts of clay rise to the surface, fig. 8. The phenomenon is not changed in any way by inserting a geotextile between the two layers.

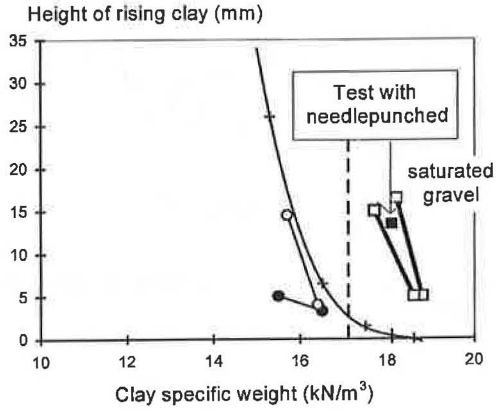

Figure 8 : Low influence of the geotextile when the gravel is saturated.

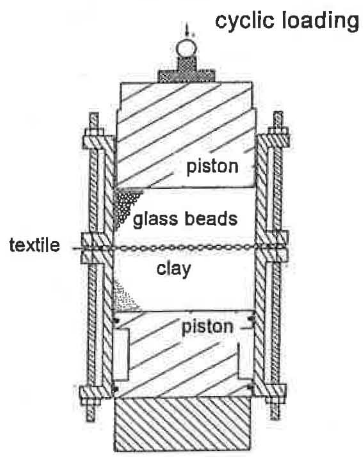

Figure 9 : Cell used for cyclic loading tests on soft clay.

4. TESTS ON SOFT CLAY

During the preceding tests, the geotextile was seen to play a very important role, especially for subsoils of insufficient compactness and with high water content. A different experimental procedure, easier to set up and implement, was used to study the behaviour of the different textile structures.

4.1 *Principle of the studies performed*

In a large oedometer cell (0.15 m diameter), a geotextile specimen is laid between a 0.10 m thick layer of clay (the same as previously) and 0.10 m of granular medium : 10 mm diameter glass beads. By using glass beads, it is possible to have a coarse granular material in which it is easy to collect the soil that has passed through the geotextile. Moreover, the shape of the grains in contact with the geotextile is always the same (better reproducibility).

The soils-geotextile specimen is compressed symmetrically by two pistons (fig. 9). Cyclic loading is applied : 100 kPa, 1 Hz frequency, up to 40 000 cycles. The clay is saturated and slightly consolidated : $\gamma_d = 11$ kN/m^3, w = 48% and very soft ($w_L = 53\%$).

4.2 Results obtained

The main results obtained are given on figures 10 to 13. Note that, after the designated number of cycles, the soil is taken from the glass beads ; each point on the graphs therefore represents a different test.

Generally speaking, the structure of the geotextile has no specific effect on overall settlement of the clay layer (El Amir, 1991). Similarly, the water content, specific weight and cohesion profiles are not influenced by the geotextile structure.

4.2.1 Mass of soil moved

The total mass of soil moved is the sum of the mass of soil trapped in the geotextile and the mass of soil collected in the glass beads. This total mass varies in a different manner according to the heatbonded or needlepunched structure of the geotextiles (fig. 10).

Under 10 000 cycles, the heatbonded geotextiles are better at containing the clay than the needlepunched material of the same mass per unit area and same filtration opening size. Beyond this figure, they are less efficient and soil movements increase.

4.2.2 Water content of the moved soil.

The water content of the displaced soil was measured (figure 11). With increase in water content, the drying effect of the clayey soil becomes greater. This is an interesting indication since this effect promotes soil consolidation in the vicinity of the geotextile. At the start of the test, the water content is very high (1000%) for woven tape heatbonded materials. They are therefore highly efficient with regard to the drying phenomenon. However, after 20 000 cycles, the water contents obtained (cumulative values) are of the same order of magnitude regardless of the geotextile, except for the monofilament woven material which produces virtually no drying effect.

On soft clay, this enhanced drying effect of the heatbonded materials is related to their higher strain modulus which, in the short term, leads to a membrane effect which confines the soil better than the needlepunched geotextiles. The needlepunched materials have a lower modulus for small strain values because of their more flexible structure and this induces « soil moulding » during the first 10 000 cycles. After that, once a certain strain rate has been reached, the modulus of the needlepunched materials increases and the membrane effect plays a more predominant role. Soil retention then becomes more efficient. As the heatbonded geotextiles are thinner, they more readily transfer the point stresses of the glass beads, and on densified soil a punching effect appears. Thus the soil, moved with the heatbonded materials, has a lower water content.

4.2.3 Mass passing through :

The long-term behaviour of the gravel layer (in this case the glass beads) will depend on the height to which the clay rises, i.e., here the quantity of soil collected in the beads (figure 12).

It is clear that, under these separation conditions, non-woven or woven tape geotextiles are indispensable : the mass of soil passing through the woven meshes of monofilaments with the same filtration opening size is much too high (fig. 12 : 1.5 kg for 1000 cycles and 8 kg for 10 000). The mass passing through the needlepunched geotextile would seem to be proportional to the log of the number of cycles (figure 12).With regard to the mass of soil passing through the heatbonded and other geotextiles, this increases considerably between 5000 and 10 000 cycles. Tests at 100 000 cycles are needed in order to confirm this trend.

4.2.4 Soil trapped in the geotextile

Needlepunched non-woven geotextiles are thicker than heatbonded materials for the same weight per unit area. As a result, the mass of soil trapped in the needlepunched materials is greater (fig. 13a). On the other hand, in terms of pollution rate, i.e. mass of trapped soil divided by volume of voids (volume of voids = nT_g where n is the porosity and T_g the geotextile thickness), the needlepunched materials have better long-term behaviour than the heatbonded ones (fig. 13b). This confirms Loubinoux's results (Loubinoux et al, 1982).

5. FULL SCALE TESTS (VIBROGIR) - GEOTEXTILE BEHAVIOUR

SNCF carried out numerous simulations of railway track subgrade behaviour under train-induced stresses by means of Vibrogir tests : a sleeper of a railway track is subjected to a 20 tonnes load with a frequency of 50 Hz. The sleeper lies on a track subgrade at full-scale. A diagram of the principle of the system is shown in figure 14.

Several types of geosynthetics of similar filtration opening size and of weight per unit area ranging from 280 to 420 g/m^2 were tested in order to define those which best meet the requirements for long-term stability of the railway track.

- The woven materials revealed damaged points and cut threads,
- The three heatbonded non-woven geotextiles tested proved to be practically impermeable after the tests in the part subjected to dynamic loading. On the

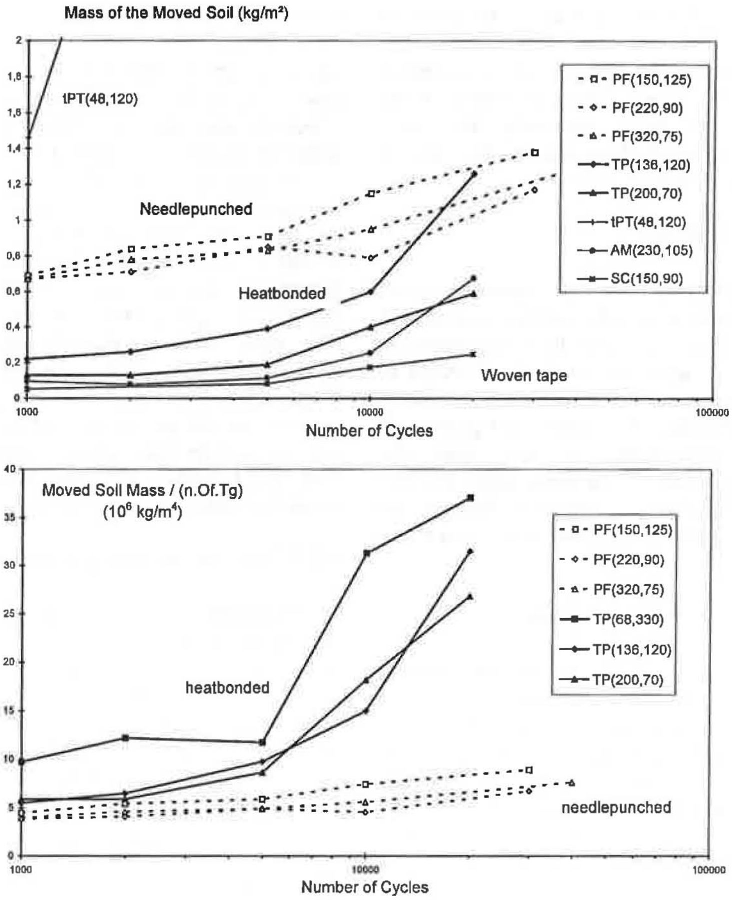

Figure 10 : Variation in moved soil mass as a function of number of cycles. Influence of the non-woven structure (n : porosity, T_g : thickness, Of : filtration opening size of geotextile).

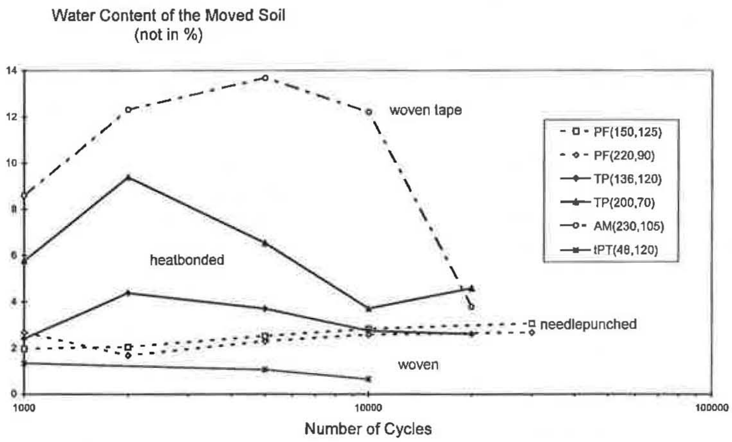

Figure 11 : Variation in water content of the moved soil mass as a function of number of cycles. Influence of the structure.

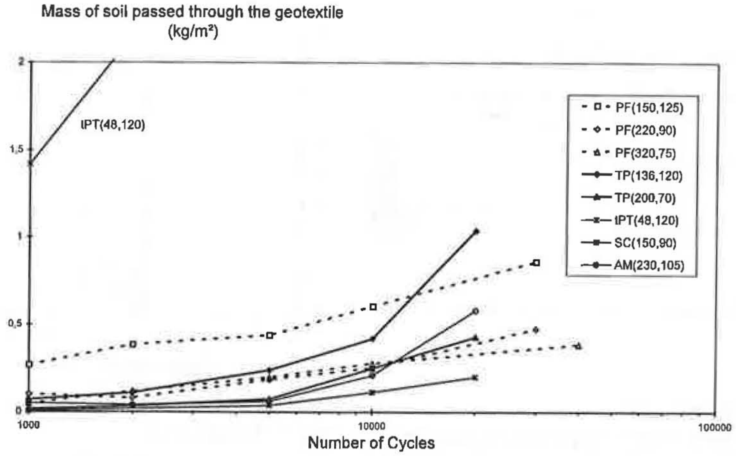

Figure 12 : Influence of structure on the mass of soil passing through the geotextile.

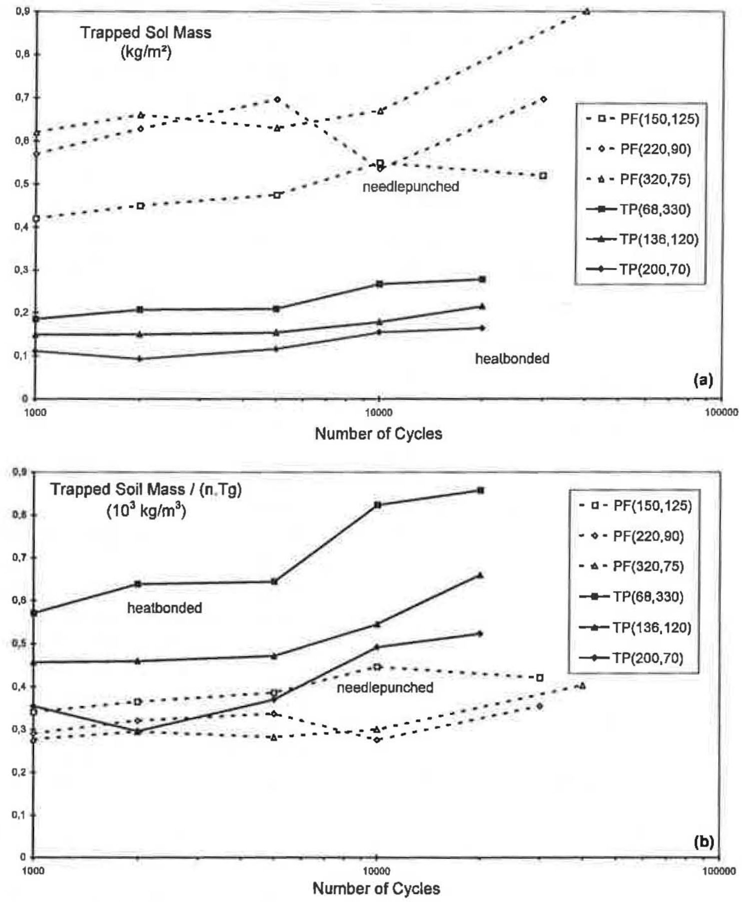

Figure 13 : Variation in mass of soil trapped in the geotextile as a function of number of cycles. Influence of geotextile structure.

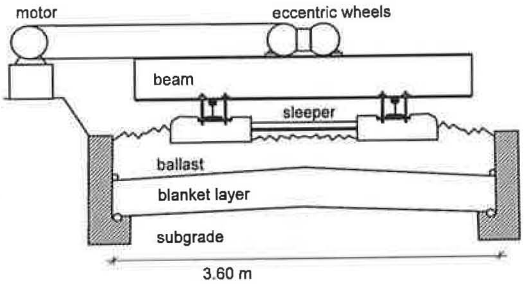

Figure 14 : Schematic cross-section through the « Vibrogir ».

other hand, all the needlepunched non-woven materials maintained a similar permittivity regardless of the nature of the subsoil : clay, sandy clay or marl, compacted to 95% of NOP at optimum water content.

In the Vibrogir tests, after 200 hours of operation, the height of the blanket layer polluted by rising fine materials above the needlepunched non-woven geotextile was limited to 3 to 4 cm.

At the base of the blanket layer, the proportion of polluting fine elements was estimated by means of methylene blue tests :

- heatbonded : 4 to 8% of the fine fraction, but the heatbonded material was completely clogged and acted as a watertight membrane,
- needlepunched : 10 to 18% when the mass per unit area of the geotextile is reduced from 400 to 320 g/m^2,
- woven : 20 to 25%.

The Vibrogir tests confirm the observations made during the tests on compacted clay (§ 3) : the clay fines rising in the gravel with a heatbonded material are more compact than those through the needlepunched geotextile. These form a sort of barrier of lower permeability (confirmed by permeability measurements in the heatbonded materials), which restricts the amount of rising mud in the longer term.

6. CONCLUSION

These tests provide essential information for the construction and refurbishment of railway line subgrades, namely :

The subsoil must be compacted at least to the NOP value and, if possible, to the Modified Optimum Proctor (MOP), and must have a high consistency index I_c as shown in figure 15.

$$I_c = \frac{w - w_P}{w_L - w_P}$$

W_P : plasticity limit and W_L : liquidity limit.

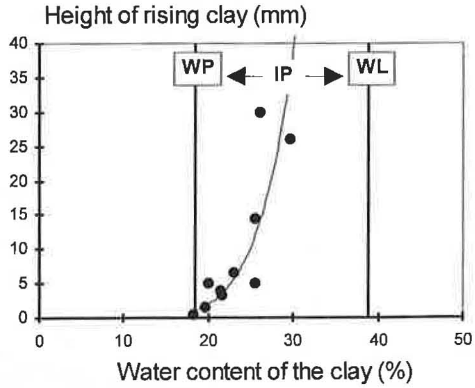

Figure 15 : Influence of the consistency index on height of rising mud.

If this condition cannot be achieved, it is absolutely essential to place a geotextile between the two layers. In cases where old track is being refurbished, with considerable construction constraints, it would be desirable to make provision for a geotextile. In addition, it is essential to provide effective drainage of the railway track subgrade.

The Vibrogir tests would seem to confirm the observations made during the compacted clay tests (§ 3) : clay fines rising in the gravel with a heatbonded material are more compact than those through the needlepunched geotextile. These form a sort of barrier of lower permeability (confirmed by permeability measurements in the heatbonded materials), which restricts the amount of rising mud in the longer term.

REFERENCES

El Amir A. (1991) : Séparation et filtration des sols cohérents par géotextiles, *Thesis University Joseph Fourier of Grenoble*, 296 pages.

Faure Y.H, El Amir A. (1990) : Separation function of geotextiles laid on a soft clay, *4th International Conference on Geotextiles, Geomembranes and Related Products*, The Hague, The Netherlands, Vol.1, page 253.

Faure Y.H., Gourc J.P., Sundias E. (1984) : Influence of the Filtration Opening Size on Soil Retention Capacity of Geotextiles, *Flexible Armoured Revetments*, Thomas Telford Ltd, London, pp 71-84.

Loubinoux D., Faure Y.H., Gourc J.P., Machizaud Ch. (1982) : Behavior of Geotextiles as filters under Dynamic and Static Conditions, *2nd International Conference on Geotextiles*, Las Vegas, USA, Vol 1, pp 43-48.