Geosynthetics - 7th ICG - Delmas, Gourc & Girard (eds) © 2002 Swets & Zeitlinger, Lisse ISBN 90 5809 523 1

Geosynthetic protection of ballast and sub-grade in railway foundation structures

R. N. TEBAY, University of Leeds, UK
C.A. LAWRENCE,The University of Leeds, UK
V. R. CADDICK, Geofabrics Ltd, UK
R. G. WARWICK, Geofabrics Ltd, UK

ABSTRACT: The paper examines the use of separators and protected membranes and geocomposites in the substructure of railway foundation engineering. It looks at the various performance & cost benefits for plain separator geotextiles, protected membrane geocomposites and protected drainage layer, membrane and protector geocomposites.The benefits for service life, track access, capital investment versus concrete sub-grades and speed of construction are also compared.

1 INTRODUCTION

1.1 *Background*

There is a drive across the UK and Europe to increase both the rail freight (by 80-%) and rail passenger transport (by 50-%) over the next five to ten years[i.] From this desired increase in rail traffic rises the need for a greater amount of Track Access Time (TAT). As such there are two alternatives to increase the amount of TAT for rail traffic.

1. Build more track
2. Increase the access time to existing track.

The first option is expensive with new rail costs running at over $2-M per mile[ii]

The second option constitutes a reduction in the amount of time the track is being serviced either by extending the service intervals or by reducing the time needed to service the live track. It is in pursuit of this second aim that this research is concerned.

1.2 *Settlement problems with soft london clay subgrades in UK rail network.*

'Rail line has to maintain line and level'[iii] that is to maintain a uniform direction (not weave) and uniform rail height (not undulate). However, over time rail line will settle due to ballast settlement, sleeper erosion and most importantly settlement of the ballast into the sub-grade. This settlement of the ballast into the sub-grade is significant in areas that have rainfall coupled with poor drainage. As the rainwater washes through the ballast into the sub-grade it significantly reduces the modulus of the underlying structure (normally clay or fine compacted soils) allowing the sub-grade to be disturbed and distorted.
In addition to the reduction in sub-grade modulus a factor starts to occur called 'Erosion Pumping Failure' whereby the fines in the sub-grade form a suspension in the water and are pumped by the action of the rail traffic into the voids in the ballast above. This erosion pumping failure constitutes significant settlement of the line. A cross sectional representation of a typical rail line set-up as employed in the tests can be seen in figure (1) below.

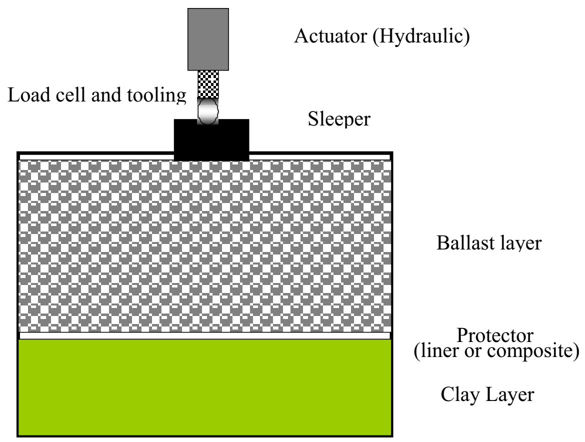


Figure 1.

1.3 *Research objectives*

The aims of this research are three fold, firstly to stop the ingress of water and or rail contaminants from the ballast above (and hence stop erosion pumping failure); secondly, to prevent the movement of ballast into the underlying sub-soil and thirdly, to aid in the dissipation of moisture from the sub-soil into to a side drain or pipe. All of which will prolong the service life of live track.

1.4 *Previous research in rail sub-grade separation*

Research was undertaken in the mid 80's by Dr Emanuel Awoleye[iv] who undertook an examination of separation between the ballast and subgrade. His conclusions were that the inclusion of a membrane and separator was unsound and that after relatively short service intervals the membrane became punctured and trapped the water between itself and the sub-grade and positively worsened the performance of the structure. However, due to limitations with the research test rig the research was undertaken…

a) in a rig not truly representative of a rail line
b) whilst adding water that was allowed no drainage
c) added water until the liner failed!
d) With a sleeper size to ballast size ratio that was in error by a factor of 4:1

The rig was only 0.9-m x 0.6-m and only 0.5-m deep. The footprint of the rail sleeper was 75-% smaller than a real sleeper yet the ballast was full size as such the sleeper penetrated the ballast significantly a factor rarely seen in day to day live track.
The stupefying factor was that water was added ‘until the liner failed’ and as the box in which the liners were tested was sealed (no drainage allowed) once the water had been added it had nowhere to go except into the clay. Even with a membrane liner the water would find its way around the edges of the membrane (within the box) and into the clay and without drainage would penetrate the clay and cause severe differential settlement causing the liners to tear and hence fail.

2. RAIL TEST RIG SET-UP

2.1 *rail test rig set-up*

The rig is much bigger than the first test rig being 4.2-m by 1.8-m and loading actuators that can load up to 120-kN at 10-Hz. As such we can replay 3-years of live rail usage in a little over 1-week working a two shift system.

Sleeper size is 90-% of the footprint of a full size rail sleeper and the ballast to sleeper ratio approaches that of real life.
There are drainage holes at various levels throughout the box allowing us to create water tables, run off drainage and monitor inflow versus outflow. All-in-all it is a controlled realistic live track environment to trial rail products with none of the risks associated with live track access and trialling. A picture of the large rig can be seen below in figure (2)

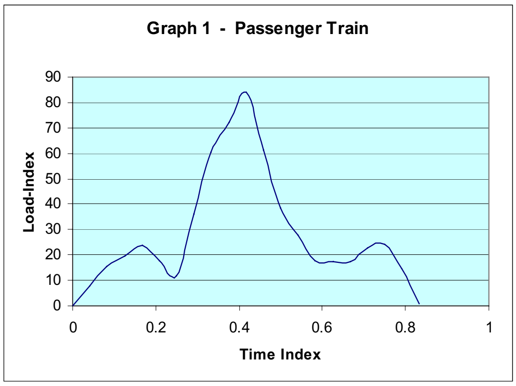
All test set-ups consisted of 800-mm ballast layer, test geocomposite and 500-mm clay layer, all tamped
All 1-M cycles, 10-Hz with complex user defined wave + 0.2 to 9.25-tonne loading (mixture of local, freight & high-speed train profiles). All had drainage off allowed.

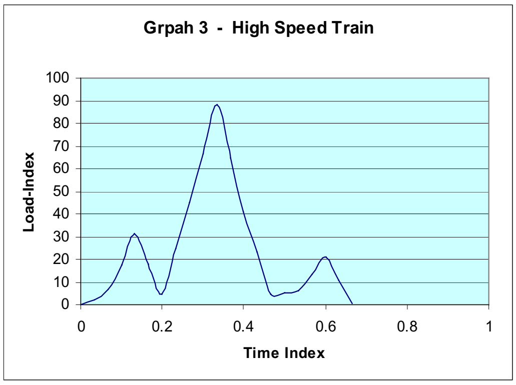
2.2 D*ata replay ability of the new rail test rig set-up*

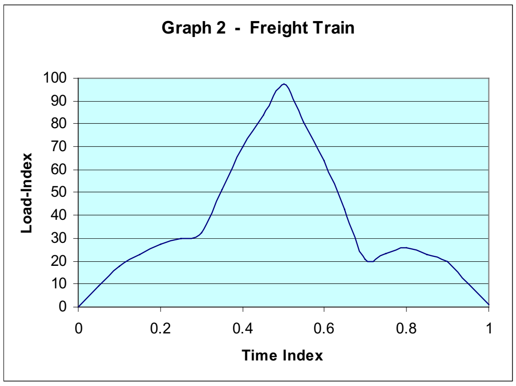
The test rig set-up as derived from the shortfalls in the first test rig has resulted in a rail test rig that is truly ‘state of the art’.
The rig has the ability to ‘replay’ train loading profiles such as those shown in graphs 1 to 3 and having three hydraulic actuators can load the rail in sequence as seen in real life with the waveforms progressing down the line

.

Figure 2. Rail test rig.







From the above graphs all have similar profiles being three peaks and troughs over time. The graphs were from research carried out in the United States by a consultancy firm that showed the waveforms had three peaks due to the following phenomena.

1. A loading sine wave that ran along the track in front of the advancing train wheel (preceding track bough wave)
2. The loading of the actual train wheel over the sensor point (the big peak).
3. A residual following wave that runs along the rail metalwork after the train ahs passed.

The research concluded that for given rail, sub-grade and wheel moduli the maximum train speed using conventional lines would be 550-kph!!
All the above data profiles were used in the proving of the geosynthetics composites in order to give the test data a realistic loading regime and provide definitive answers to the relative advantages of each product over the other.

3 RESEARCH FINDINGS

3.1 T*est profiles & objectives*

The main areas of examination were to look at the efficiency of…

1. Geotextile Separators in wet rail environments
2. Geocomposite (Felt / Membrane / Felt [FMF]) separators in wet rail environments
3. Geocomposite (Felt / spacer Net / Felt [FNF]) Separators in wet rail environments with run off and little inclement wetting (tunnels).

&

4. Geocomposite (Felt / Net / Membrane / Felt [FNMF]) High Drainage separators in wet rail environments

The aims for the nonwoven elements are to inhibit the erosion and penetration damage as seen when the sub-soil becomes wet and to protect any membranes and spacer grids used in the geocomposites from stone damage and sub-soil ingress.

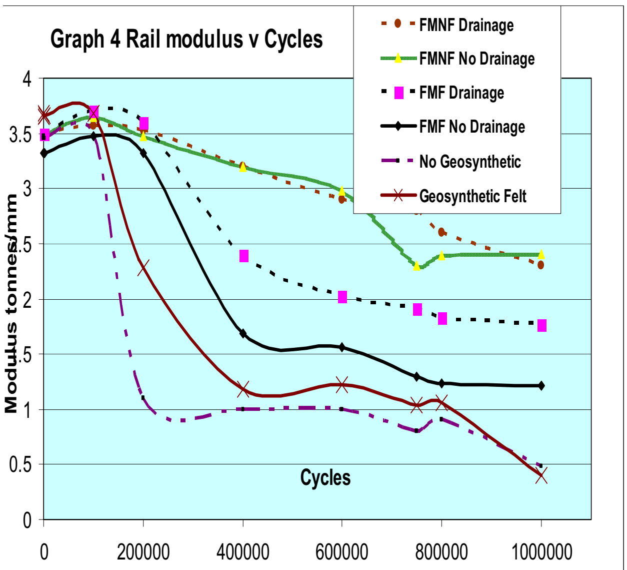
The aims for the membrane are (as always) to prevent the movement of any substances from the aggregate above or the sub-soil below and hence to keep the sub-soil dry and thus firm.

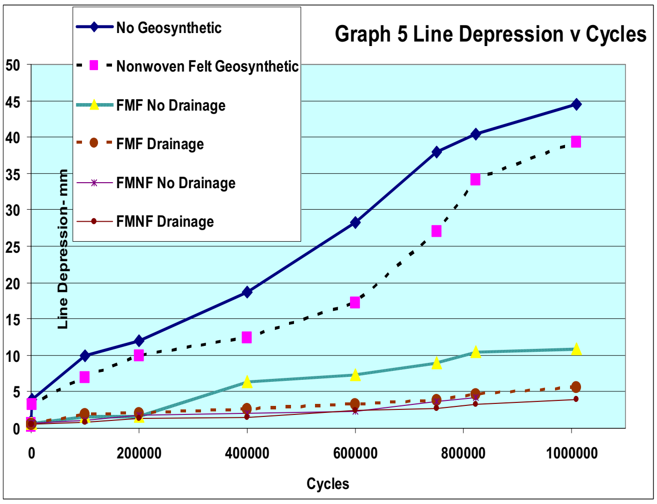
The aims for the spacer geogrids are to provide an open network between the geocomposite layers and allow water rising from below the separator layers to pass off the areas below the line to drainage conduits where it can be controlled.

All tests were carried out 'wet' with 350-litres of water being added to the tank over the first 200 000 cycles. All the tests had identical loading profiles with mixtures of high speed, local passenger and freight trains at peak loading levels.

4 RESULTS

The graphs below depict the line settlement versus time for the 4 main structures as listed above with graph one being a 'control' test with no Geotextile included in the test.





4.1 Analysis of Raw Data

From the above two graphs two factors become evident.

1. That the inclusion of a membrane layer is extremely effective in maintaining the modulus of a sub-soil despite extreme water addition.
2. The inclusion of a spacer grid augments the transport of water off the surface of the sub-soil.
3. The use of a plain nonwoven has little long-term effect on the performance of the sub-soil structure and modulus as the fines wash into the added water and through the non-woven inhibiting erosion pumping failure but not stopping it

5 CONCLUSIONS

The above results do indeed re-enforce the idea that the use of geosynthetics and more specifically geocomposites are of significant benefit when used in live rail structures.

Indeed they can give a trebling of service interval when used in the right areas and when the sub-structures are constructed to include a run off for rainfall. In all civil engineering structures it widely held as a 'written in stone' that control of water on site is the most important factor for the long term performance of the construction be it buildings, roads or railways.

However, the use of the geosynthetic must be calculated and site specific to give the optimal benefit and as such the author has recommended the following geosynthetics given the listed site conditions…

1. A geocomposites consisting of a membrane sandwiched between two protective, light weight (400-gsm) non-wovens if the site has little risk of water ingress from an underlying water table.
2. As above but with the addition of a spacer grid to allow the passage of water from the underlying soil if contamination from a raised water table is a problem. In addition, with the inclusion of a drainage pipe if there is a risk of high water ingress (from either the underlying water table or rainfall) in order to control and speed the expelling of the water from the site.
3. Use of a single separator (non-woven only) can only be advised in specialist circumstances with structures with significant fall off and low rainfall otherwise the following quagmire can still result…

4. On site drainage plays a significant part in the uneven settlement of railway lines and leads to the premature downgrading of the line speed [v]. Keeping a ground with a sub-structure as dry as possible is therefore a distinct step towards preserving this ideal and the use of specifically targeted geocomposites (Geocomposites designed in sympathy with all the site conditions) is the best way forward to ensure this. In

specifiers in the rail industry so that the benefits of geocomposites are evident (by further research and collaboration). Further, they (the specifiers) must have a working knowledge of Geosynthetics and their benefits and shortcomings so that they are confident in asking for the products that the sites require so that both industries can step forward on a firmer footing.

Figure 3. end panel removed noting complete aggregate / sub-soil separation by light-weight non-woven despite high water addition (300-l).

Figure 4. quagmire after use of non-woven separator (as above in figure 3) without membrane or geogrid spacer

FURTHER WORK

Work is currently on-going in this rig as it gives us the ability to realistically look at the effects, performance and set-up criteria that are important in extending the service life and service interval of line train track and hence increase the Track Access Time crucial for today's modern transport systems.

Areas currently under investigation include…

1. Drainage pipe positioning, type, size and specification &
2. The use of sound absorbing mats to reduce sound intrusion and vibration damage to domestic housing, bridges and other similar structures.

[I] UK Department of Transport Whitepaper
[II] Railways engineering Conference April May, UK 2001
[III] Geoffrey H Cope (Editor) 'British Railway Track – Design Construction and Maintenance' Edition 6, 1996 Echo Press Leicestershire.
[IV] Awoleye, E., Jarvis Rail, York.
[V] Geoffrey H Cope (Editor) 'British Railway Track – Design Construction and Maintenance' Edition 6, 1996 Echo Press Leicestershire