The Fifth International Conference on Railway Technology
RAILWAYS 2022
22–25 August 2022
Montpellier, France

Proceedings of the Fifth International Conference on
Railway Technology:
Research, Development and Maintenance
Edited by J. Pombo
Civil-Comp Conferences, Volume 1, Paper 8.5
Civil-Comp Press, Edinburgh, United Kingdom, 2022, doi: 10.4203/ccc.1.8.5

Long-term Monitoring of a Geogrid Installed Beneath a Subballast Layer in Operating Conditions

O. A. Yaba[1, 2], F. Emeriault[2], O. Jenck[2], J.-F. Ferellec[1], A. Dhemaied[1]

[1] DGII–GC–VA–CIR , SNCF Réseau, La Plaine St Denis, France
[2] CNRS, Grenoble INP, 3SR, Université Grenoble Alpes, Grenoble, France

Abstract

The use geogrids to improve railway track beds is one of the solutions proposed by the French National Rail Company (SNCF) to conduct renovations. This paper presents a monitoring scheme which was installed one of these improved track beds. It provides practical feedback concerning the installation process and an analysis of the preliminary results.

Keywords: instrumentation, geogrid, subballast, SNCF.

1 Introduction

The increase in rail traffic and traffic speeds impose large cyclic loads on the French Rail Network's (FRN) track beds, thus contributing to the appearance of defects in track geometry. These defects can impact train safety and passenger comfort. SNCF (French National Rail Company) has launched major renovations to address these problems on its conventional (non-high speed) rail network. Meanwhile, railway infrastructure managers are faced with increasingly stringent environmental and budgetary challenges. All these constraints sparked a search for innovative solutions which could enable renovations to be carried out at a lower cost while guaranteeing the network's structural resilience and ensuring that modern environmental standards are respected. One potential solution is the use of geogrids to improve railway track beds. Geogrids are geosynthetics that are used in the construction industry in the form of a reinforcing or stabilizing material [1]. They have planar structures formed by a regular network of tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock, earth, or any other geotechnical material to perform their functions [2].

Presently, knowledge on the mechanical behaviour of geogrids and their contributions to the improvement of railway operating conditions is limited. Most studies in the field have focused on the interaction of geogrids with the ballast layer [3]-[7]. These studies have shown the effectiveness of geogrids in reducing ballast wear and lateral spreading. However, they do not allow one to draw satisfactory conclusions regarding the improvement of the subballast layers. In addition, for several reasons, the installation of a geogrid in (or immediately below) the ballast layer is not compatible with the FRN's operating conditions (maintenance techniques, traffic, etc.). Hence, it is interesting to set up an in-situ experiment on the FRN which measures the strains on a subballast geogrid, as well as the stresses and settlements in the track bed. The aim is to quantify the improvements provided by a geogrid which is installed beneath the subballast layer (in operating conditions), and to study the mechanisms by which this improvement is achieved.

2 Methods

The monitoring equipment was installed on a 30m stretch of track with daily traffic of 80,000 to 130,000 equivalent tonnes. The stretch is near a turnout (switch) with a 90km/h speed limit. The monitoring equipment was installed during the renovation of approximately one kilometre of track, which was proposed in conjunction with the routine replacement of the turnout.

The preliminary investigations revealed the presence of a weak subgrade composed of silty-clay, beneath the track components (rail, sleepers and ballast). The renewal of track components could have worsened the situation; thus, a geogrid was included beneath the proposed subballast layer, to reduce the volume of required earthworks and improve bearing capacity. A multiaxial geogrid with a secant modulus of 480kN/m at low strain (0.5%) and 100% junction efficiency [8] (according to the manufacturer) was chosen. Lightweight Falling Deflectometer tests were performed during the earthworks (using a minidyn™ [9]). They confirmed that the subgrade was indeed weak (Ev2 stiffness ≤ 30MPa).

The monitored stretch is divided into 4 cross-sections (labelled S0 to S3, see figures below) which can be identified based on their distance from a nearby sign post. S0 is a control section (no geogrid) while the other 3 are improved using the geogrid. The monitoring scheme consists of the following sensors.

- 9 strain gauges (bonded to the geogrid): to measure rib strains and track them over the long-term (Figure 1).
- 2 temperature probes: to measure the geogrid/subballast temperature and apply thermal corrections (Figure 1).
- 5 total pressure cells: to measure soil stresses (Figure 2).

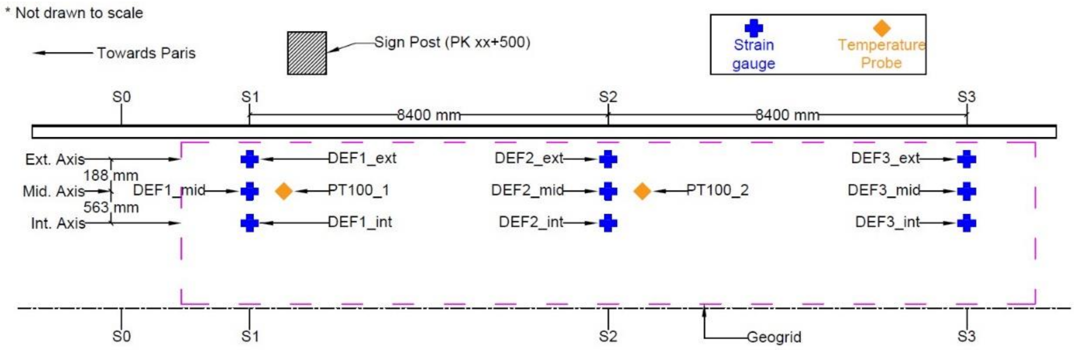

Figure 1: Strain gauge and temperature probe locations (plan view).

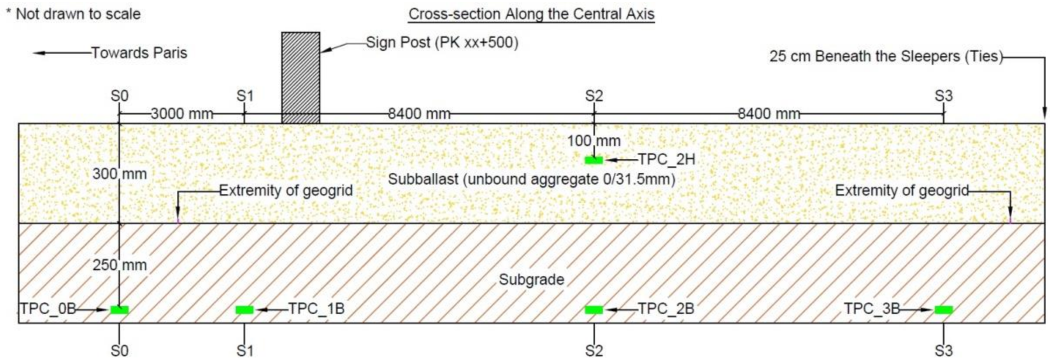

Figure 2: Pressure cell locations (cross-section).

The characteristics of each type of sensor are summarized in Table 1. Note that they were reused on this site following the cancellation of a previous site and therefore, may be inadequate (with regards to the orders of magnitude of our measurements).

The sensors were connected to a Campbell Scientific CR-1000 datalogger, which takes measurements every 10 minutes and records the average of the 6 measurements taken every hour. This preliminary approach has been deemed inadequate. More powerful dataloggers will be used on future sites in conjunction with a trigger system. Thus, enabling dynamic measurements during the passage of trains.

Sensors	Manufacturer	Reference	Measurement Range	Precision	Resolution	Operating Temperature
Strain Gauge	Micro-Measurements	EP-08-015DJ-120	±10%	0.02µm/m	0.001µm/m	-75 to +205°C
Temperature Probe	RS-Pro	PT100	-20 to +200°C	±0.15°C	0.01°C	-20 to +200°C
Total Pressure Cell	Telemac	TPC 229mm	0 to 2000kPa	±10kPa	0.5kPa	-50 to +150°C

Table 1: Sensor specifications

3 Results

For context, the sensors were activated in September 2019, after tamping and installation of the track superstructure (ballast, sleepers and rails). Hence, the recordings do not include the effect of tack construction or the initial loading applied by construction equipment. The renovation of track components continued above the monitored trackbed until October 2019. Normal traffic was restored in mid-October; it consists mostly of passenger trains (approximately 4 trains/hour) and occasional freight trains (at night). The current results provide insight into the seasonal behaviour of the embedded geogrid and allow one to draw some qualitative conclusions.

The first observation is that since the first recordings, the geogrid has experienced a net contraction (positive strain, according to geotechnical convention) as shown in Figures 3 to 5. These strains have reached a plateau, at very low values. These strains are around 1μm/m for S2 and S3. Strains are higher at S1, up to 4μm/m, most likely because it is closest to the edge of the renovated area.

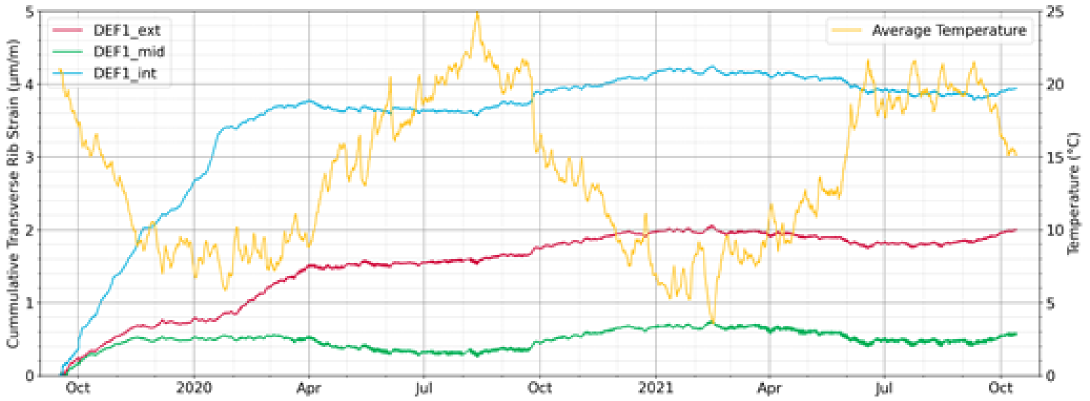

Figure 3: Cumulative strain and corresponding temperature at cross-section S1.

Figure 4: Cumulative strain and corresponding temperature at cross-section S2.

Figure 5: Cumulative strain and corresponding temperature at cross-section S3.

Secondly, the recorded strains result mainly from temperature fluctuations, which thermal contraction compensating for any cumulative extension caused by train loads. This influence is apparent when comparing the temperatures to the strains plotted on Figures 3 to 5. The seasonal variations are more evident if strain is plotted against temperature. An example of the seasonal breakdown and its total result is shown, for DEF3_ext, in Figure 6.

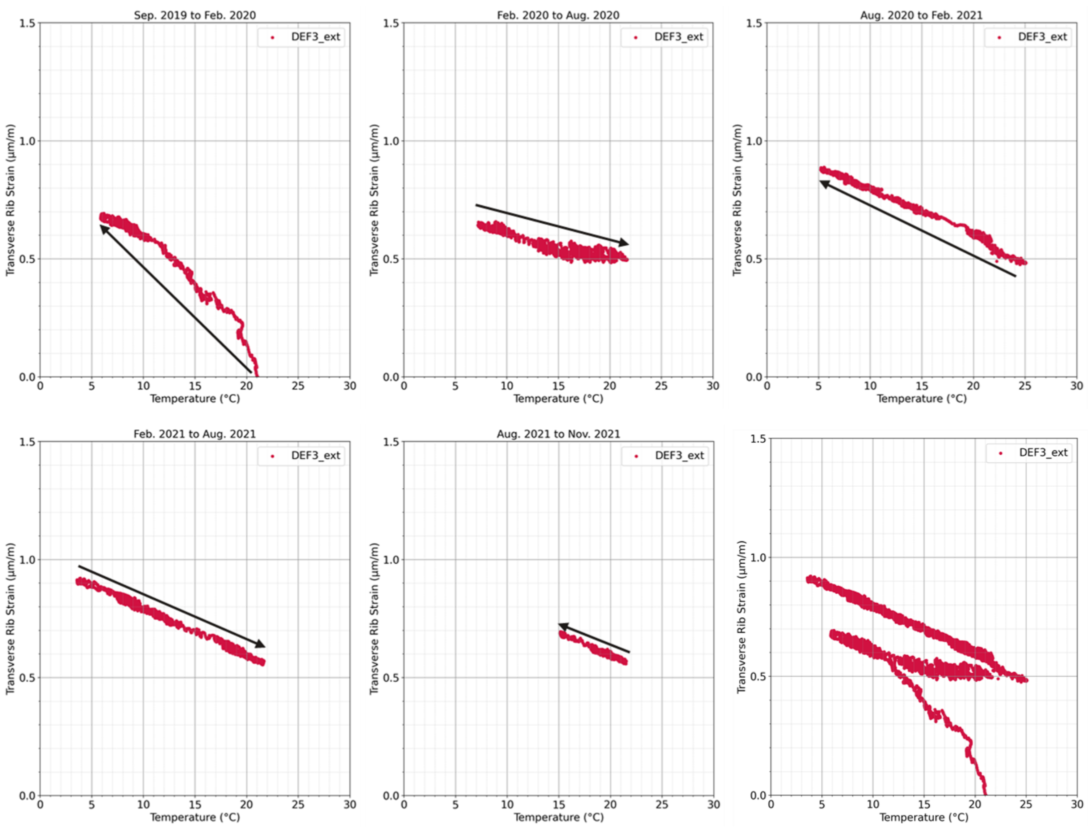

Figure 6: Seasonal breakdown for strain relative to temperature for DEF3_ext.

This behaviour is the same in all other sections. The thermal sensitivity of the geogrid is currently being analysed in the lab. This analysis, coupled with the recorded strain measurements, will facilitate the extraction of the strains that result from mechanical stresses. Thus, providing a better understanding of the stress-strain behaviour.

Finally, soil stresses are in line with expectations, with the upper total pressure cell (TPC_2H) bearing less stress than the others (Figure 7). However, the total pressure cells where initially intended for another site, so their precision is not ideal for identifying changes in the current installation. Despite this, they will be useful for detecting any large shifts within the trackbed over the long term.

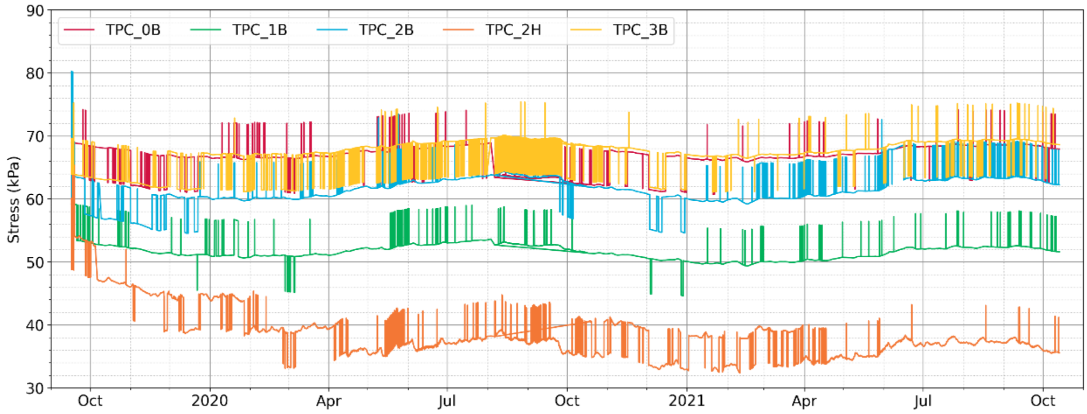

Figure 7: Soil stress in the track bed.

4 Conclusions and Contributions

This paper presented the implementation of a monitoring scheme for a railway track bed which was improved using a geogrid. The experiment has shown that it is not only possible to implement this type of scheme under standard operating conditions on the French Rail Network, but also that it is possible to do so without damaging any sensors during installation. Analysis of the preliminary results has shown that all the installed sensors are still functional, that the system quickly reaches a plateau, and that the system can be expected to have several years of service life during which one could observe seasonal cyclicality. Furthermore, this analysis has revealed some of this monitoring scheme’s drawbacks, the most notable of which is the lack of an integrated trigger system for detecting oncoming trains. These drawbacks have been taken into consideration and the feedback has led to the improvement of the datalogging protocols for this site and the design of an improved monitoring scheme which has been implemented on other sites. In addition to these improvements, the current measurements (which are all provided by embedded sensors) will be supplemented with periodic measurements of sleeper displacement under traffic. Over the long-term, the data from this site and others like it will be used to:

- analyse the mechanisms by which geogrids can improve a subballast layer (confinement, stabilization, reinforcement, …);
- quantify the improvements that are achieved by these mechanisms;

- develop numerical models for further research on the service life of subballast layers that have been improved using geogrid;
- and finally provide detailed design and maintenance recommendations for the adequate implementation of geogrids on the French Rail Network.

Acknowledgements

The authors would like thank the various SNCF Réseau teams that made this experiment possible, especially the field measurement section (SNCF Réseau, DGII – VA – T3).

References

[1] International Geosynthetics Society, “Guide to the Specification of Geosynthetics”, IGS Secretariat, Jupiter, Florida, 2018.

[2] R. J. Carroll, “Specifying Geogrids”, Geotechnical Fabrics Report, vol. 6, n°12, 1988.

[3] L. Horníček, P. Břešt'ovský et P. Jasans, “Application of geocomposite placed beneath ballast bed to improve ballast quality and track stability”, IOP Conference Series: Materials Science and Engineering, vol. 236, n°11, p. 012039, 2017.

[4] S. Nimbalkar et B. Indraratna, “Improved performance of ballasted rail track using geosynthetics and rubber shockmat”, Journal of Geotechnical and Geoenvironmental Engineering, vol. 142, n°18, pp. 04016031-1 - 04016031-13, 2016.

[5] S. Lenart et J. Klompmaker, “Geogrid reinforced railway embankment on soft soil – Experiences from 5 years of field monitoring”, chez 10th International Conference on Geosynthetics, Berlin, 2014.

[6] G. Fernandes, E. M. Palmeira et R. C. Gomes, “Performance of geosynthetic-reinforced alternative sub-ballast material in a railway track”, Geosynthetics International, vol. 15, n°15, pp. 311–321, 2008.

[7] P. Sharpe, M. Brough et J. Dixon, “Geogrid trials at coppull moor on the west coast main line. Railway Foundations”, chez International Conference on Railway Foundations, 2006.

[8] European Organisation for Technical Approvals, “Non-reinforcing hexagonal geogrid for the stabilization of unbound granular layers by way of interlock with the aggregate”, Brussels, 2017.

[9] Rincent ND Technologies, “Plaque dynamique légère Manuel d’utilisation”, Courcouronnes, 2017.