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 10.12
Civil-Comp Press, Edinburgh, United Kingdom, 2022, doi: 10.4203/ccc.1.10.12

Monitoring of a rail expansion joint to evaluate its behaviour against climatic events

P. Martínez Fernández[1], I. Villalba Sanchís[1], P. Salvador Zuriaga[1], R. Insa Franco[1], V.M. Viñas Olmo[2], D. Pérez Mira[2] and J. Pineda-Jaramillo[3]

[1]Department of Transport Engineering and Infrastructure, Universitat Politècnica de València, Spain
[2]AZVI, S.A.U., Spain
[3]Department of Engineering, University of Luxembourg

Abstract

Climate change poses a clear threat for all human activities, including transport. Railways play an essential role in the sustainability of the transport sector, and thus their reliability against climatic events must be properly ensured. In this context, the project MINFECLIMA aims to contribute to a better understanding of the relation between the railway infrastructure, its maintenance and a changing climate. The project is developed by AZVI S.A.U. and SIER in collaboration with Universitat Politècnica de València within the framework of an International Cooperation Call funded by CDTI and the Spanish Ministry of Science, Innovation and University.

This study presents certain parts of the project MINFECLIMA, namely the monitoring of a critical element of the rail infrastructure i.e. an expansion joint. An ad hoc monitoring equipment has been designed to automatically gather data from the joint and couple it with climatic data to carry out analyses that may help determining its behaviour against climatic events.

A first assessment of the data gathered so far shows an expected trend, as there is a clear correlation between rail and average air temperature and the expansion joint behaviour. This proves that the designed system is operating as expected, as the collected data is aligned with previous experience and knowledge regarding the operation of expansion joints. Further analyses will be carried out to gain more insight into the joint behaviour.

Moreover, a large dataset is being recorded and stored as part of the ongoing project MINFECLIMA. The preliminary analysis presented here for the expansion joint is but a first step on a wider research task. This will be carried out in later stages of the

project to achieve a new understanding of the effects that climate has on the rail infrastructure and, consequently, developing more effective maintenance methodologies.

Keywords: Railways, Maintenance, Climate Change, Monitoring.

1 Introduction

Climate change poses a clear threat for all human activities, including transport. According to up-to-date previsions, extreme climatic events such as heatwaves and heavy rains will be more common and destructive in the near future [1]. Railways, due to their extensive infrastructure, need to adapt to this changing environment in order to ensure their role as a sustainable transport mode in the future.

Over the last few years, several studies have tried to quantify the impact of climatic events on railways. For instance [2], climatic factors account for between 5 and 10% of railway failures in the Netherlands. The percentage rises to 20% in the UK [3]. Among the main track defects caused directly by climatic factors, buckling stands out as a particularly severe one, as it causes more than 6000 failures per year in the European rail network, a number that is on the rise due to increasing temperatures [4]. The cost of such failures was calculated as about £9 million per year in the UK [5]. Other noteworthy climate-related failures are landslides due to heavy rainfall [6], flooding and rail breaks due to cold temperatures, although the latter is expected to become less prominent in the future. In any case, it is essential to adapt railways infrastructure to climate change, and thus international organisations such as the UIC [6] or the European Environment Agency [7] have already issued recommendations in this regard.

In this context, the project MINFECLIMA aims to contribute to a better understanding of the relation between the railway infrastructure, its maintenance and a changing climate, in order to improve the reliability and sustainability of such an essential transport mode. The project is developed by AZVI S.A.U. and SIER in collaboration with Universitat Politècnica de València within the framework of an International Cooperation Call funded by CDTI and the Spanish Ministry of Science, Innovation and University.

This study presents certain parts of the project MINFECLIMA, namely the monitoring of a critical element of the rail infrastructure i.e. an expansion joint. An ad hoc monitoring equipment has been designed to gather data from the joint and couple it with climatic data to carry out analyses that may help determining its behaviour against climatic events. In the following sections, the equipment and monitoring plan are described in detail, the first datasets obtained are presented and a preliminary analysis is carried out.

2 Methods

The expansion joint chosen for monitoring (Figure 1) is located in the Mediterranean Corridor line (Kilometric Point 62+000) in the province of Valencia (Spain). It is a common design, representative of many similar installed across the

Spanish rail network managed by ADIF (Spanish infrastructure manager). The line is used for both passenger and freight services.

Figure 1: Expansion Joint.

To monitor this section, different sensors were installed to measure rail temperature and joint movements. These are summarised in table 1, and the installation is shown in figure 2.

Temperature sensors	
Model	DS18B20
Range	-55 to 125ºC
Error	±1 ºC
Number of sensors	4
Location	Rail web
Distance sensors	
Model	PM100
Range	100 mm
Linearity	±0.075%
Number of sensors	2
Location	Joint (to measure joint aperture)
Distance sensors	
Model	HPS-S-10
Range	1000 mm
Linearity	±0.25%
Number of sensors	1
Location	Joint points (to measure their movement)

Table 1: Sensors installed in the joint.

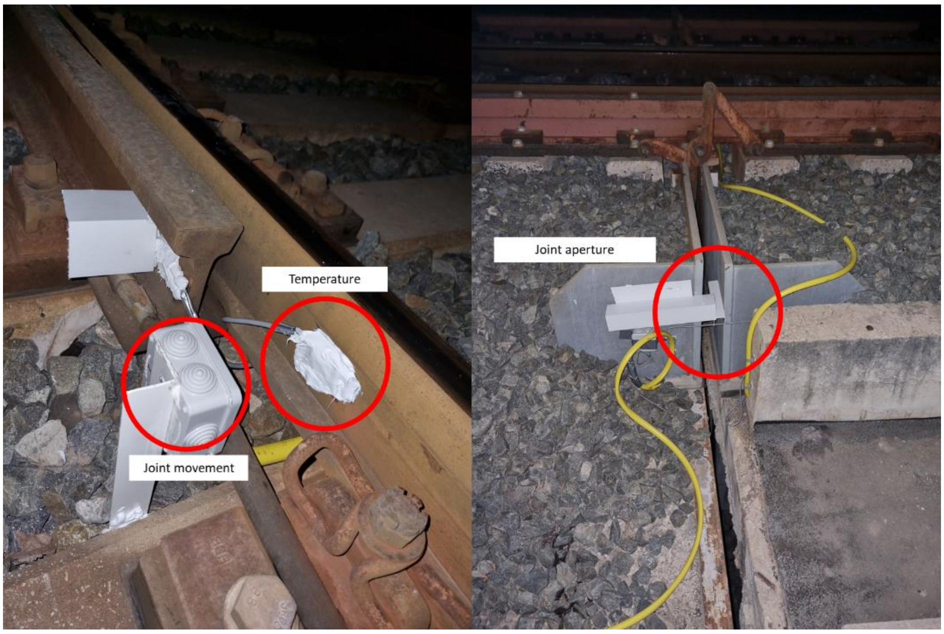

Figure 2: Sensors installation.

The sensors are connected to a Raspberry Pi 4, which is powered by a battery and a solar panel stored in an insulated box near the track (figure 3).

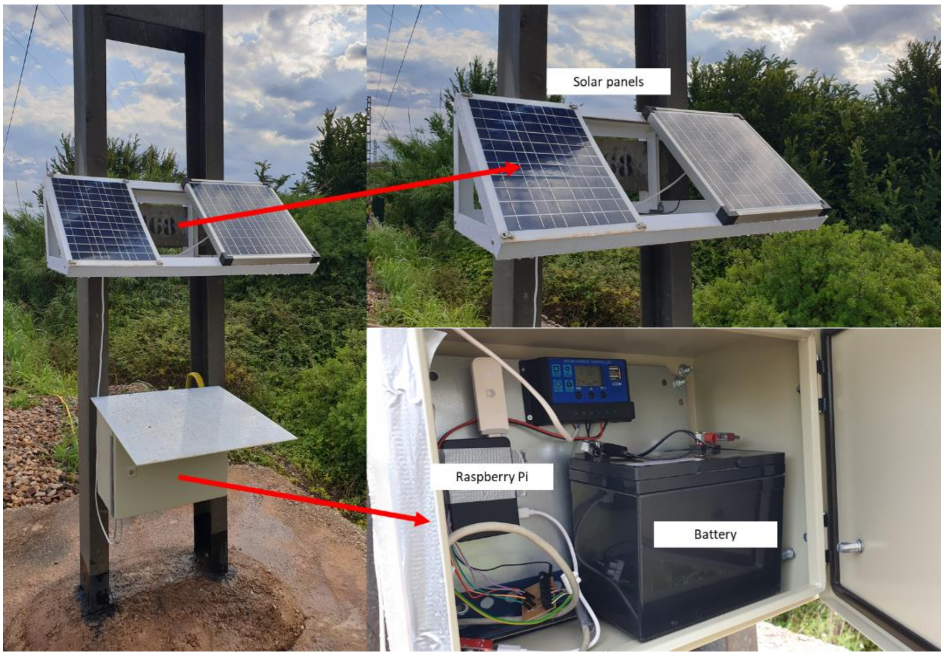

Figure 3: Raspberry Pi, battery and solar panels in a box near the track.

The system operates automatically, taking data from the sensor once every ten minutes. The data thus gathered is stored locally and synchronised with an AZURE database. Climatic data (such as air temperature and rain) is provided by the Spanish Weather Agency (AEMET) and stored also in the AZURE database.

This system was installed on July, 2021, and is expected to operate for at least one year, although the monitoring could be further expanded to 18 months within the current project timetable. During the first months of operation (until November, 2021), more than 34882 values of temperature and 32799 values of distance (in both the joint and the joint points) have been recorded and stored for analysis.

3 Results

Figure 4 shows an excerpt of the data measured in the expansion joint and stored in the database. Each line corresponds to one measurement, properly identified by a unique numerical id, time of measurement, type and number of sensor ('temp' for temperature, 'desp' for joint aperture and 'dist' for joint points movement) and numerical value. As explained, the system takes one measurement for each sensor every ten minutes.

Data Output Explain Messages Notifications

	dato real	id [PK] integer	num_sens integer	tipo text	hora timestamp without time zone
72010	20.5	60557	4	temp	2021-08-04 05:27:03
72011	3.34445	60552	1	desp	2021-08-04 05:27:03
72012	22.77	60551	2	dist	2021-08-04 05:27:03
72013	22.45	60550	1	dist	2021-08-04 05:27:03
72014	2.3758	60553	2	desp	2021-08-04 05:27:03
72015	22.64	60542	1	dist	2021-08-04 05:16:59
72016	3.33736	60544	1	desp	2021-08-04 05:16:59
72017	22.71	60543	2	dist	2021-08-04 05:16:59

Figure 4: Excerpt of database with data measured in the expansion joint.

Figure 5 shows the comparison between rail temperature and air temperature. Only three temperature sensors are shown because sensor number 3 malfunctioned. This failure is negligible as the sensors are redundant.

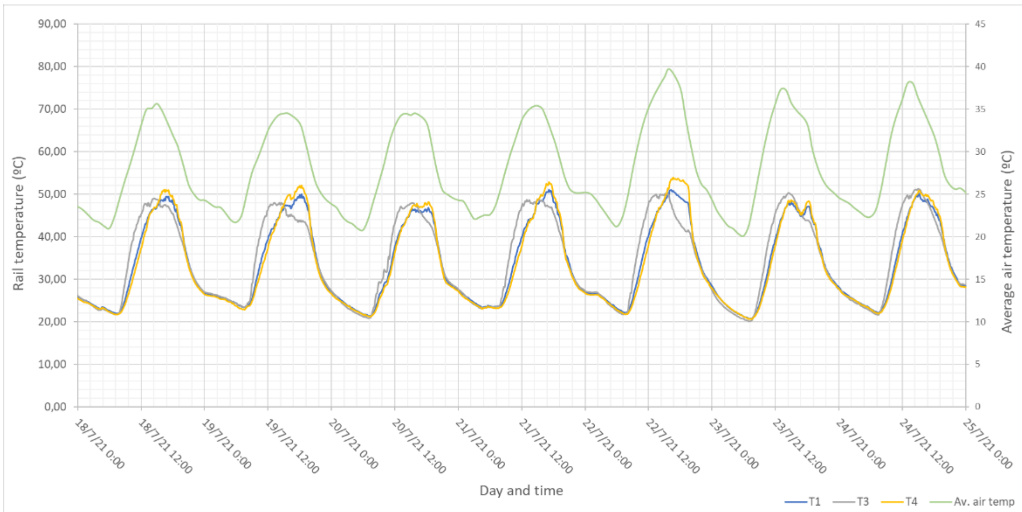

Figure 5: Rail temperature from three sensors vs average air temperature.

As the figure shows, there is, as expected, a clear correlation between rail and air temperature. The ratio between both values is approximately 1.5, a result in line with previous studies [4]. This concurs with previous studies that have demonstrated that air temperature is a significant parameter in predicting rail temperature [8], although other authors [9] propose to include additional weather conditions such as wind speed and cloud cover to improve predictions.

Conversely, figure 6 shows the comparison between average air temperature and joint aperture.

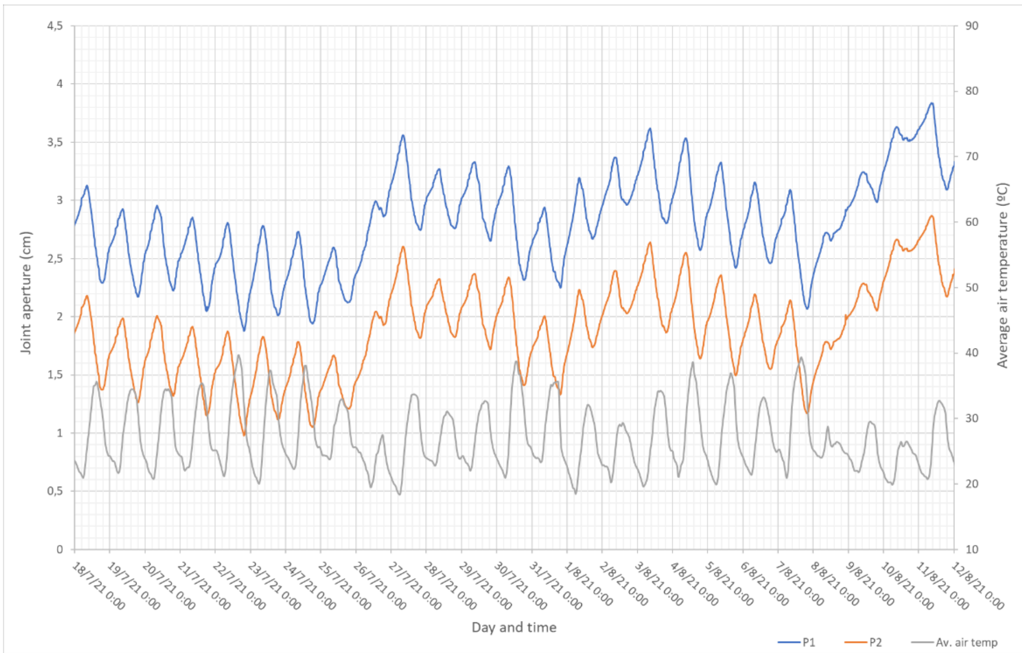

Figure 6: Joint aperture (two sensors) vs average air temperature.

Once again, the results follow an expected trend, as the joint opens and closes following daily and seasonal temperature variations. There is also a clear difference

(1 cm on average) between both sides of the joint (as each sensor is placed on one side of the double track platform), which indicate a non-fully symmetrical behaviour of the joint.

Overall the system is working as expected as it shows a proper behaviour of the expansion joint. Of course, this is only a first insight into the data gathered. The ultimate goal of the project MINFECLIMA is not to validate already known behaviour in such joint, but to gather enough data over an extended period of time to allow massive data analyses which, in turn, may help finding out long-term trends for a more efficient and sustainable maintenance of the rail infrastructure.

4 Conclusions and Contributions

This study is part of the project MINFECLIMA, developed by AZVI S.A.U. and SIER in collaboration with Universitat Politècnica de València. The project aims to improve rail infrastructure resiliency against climate change and contribute to a better maintenance of the rail network, taking into account climatic factors and their future evolution. In this context, a critical track element (an expansion joint) has been equipped with an ad hoc monitoring system designed to gather data automatically during at least one year. The data thus gathered is being stored in an online database and coupled with climatic data for analysis.

A first assessment of the data gathered so far shows an expected trend, as there is a clear correlation between rail and average air temperature and the expansion joint opens and closes following daily and seasonal variations. This anticipated behaviour proves that the designed system is operating as expected, as the collected data is aligned with previous experience and knowledge regarding the operation of expansion joints such as the one monitored. Further analyses will be carried out to gain more insight into the joint behaviour.

Moreover, a large dataset is being recorded and stored as part of the ongoing project MINFECLIMA, which encompasses the monitoring of other track elements such as drainage and embankments with a system similar to the one described here. The preliminary analysis presented here for the expansion joint is but a first step on a wider research task. This will be carried out in later stages of the project, by applying different Big Data techniques that will help achieving a new understanding of the effects that climate has on the rail infrastructure and, consequently, developing more effective maintenance methodologies.

Acknowledgements

The authors would like thank ADIF for their help and support during the installation of the monitoring equipment in their tracks.

References

[1] IPCC, “Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects”, Cambridge University Press, Cambridge, UK and New York, USA, pp. 1150, 2014.

[2] A.G.P. Duinmeijer, R. Bouwknegt, "Betrouwbaarheid Railinfrastructuur 2003" (Reliability Rail Infrastructure 2003). Prorail, Utrecht, 2004.
[3] J.E. Thornes, B.W. Davis, "Mitigating the impact of weather and climate on railway operations in the UK" In: Proceedings of the 2002 ASME/IEEE Joint Rail Conference. Washington DC, Abril 23-25, 2002.
[4] I. Villalba Sanchís, R. Insa Franco, P. Martínez Fernández, P. Salvador Zuriaga, J.B. Font Torres, "Risk of increasing temperature due to climate change on high-speed rail network in Spain", Transportation Research Part D: Transport and Environment, 82, 2020.
[5] K. Dobney, C.J. Baker, A.D. Quinn, L. Chapman, "Quantifying the effects of high summer temperatures due to climate change on buckling and rail related delays in south-east United Kingdom", Meteorological Applications, 16, pp. 245-251, 2009.
[6] A. Quinn, A. Jack, S. Hodgkinson, E. Ferranti, J. Beckford, J. Dora, "Rail Adapt. Adapting the railway for the future", UIC Report, 2017.
[7] EEA, "Adaptation of transport to climate change in Europe. Challenges and options across transport modes and stakeholders", EEA Report, 2014.
[8] C. Esveld, "Modern Railway Track", Delft University of Technology: Zaltbommel, Netherlands, 2001.
[9] S. Hong, C. Park, S. Cho, "A rail-temperature prediction model based on machine learning: warning of train-speed restrictions using weather forecasting", Sensors, 21, 2021.