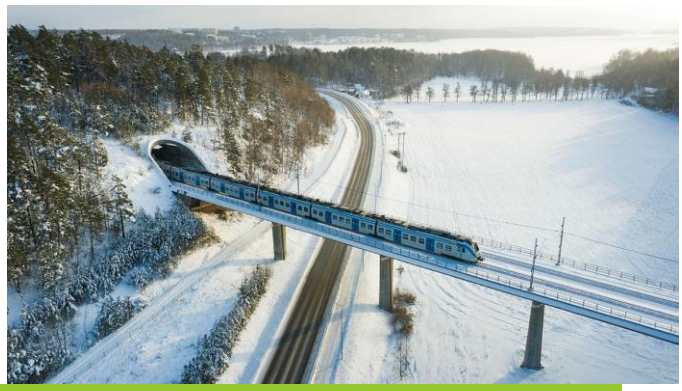
Sustainable and cost-efficient eco-design for rail assets: demonstrations from Work Package 16



DYNAMIC ANALYSIS OF BRIDGES

Under FP3-IAM4Rail Work Package 16 Trafikverket, together with the Royal Institute of Technology (KTH) and Adif with INECO, are carrying out continuous measurements of the dynamic response of bridges. Dynamic analyses are often performed for railway bridges on high-speed lines to ensure that no negative effects arise due to passing trains, such as ballast instability caused by bridge resonance. Current criteria are based on limited studies; more recent research shows that these criteria are conservative and do not reflect the actual behaviour of bridges.

The use case aims to increase knowledge of the real behaviour of ballasted railway bridges. The ambition is to capture the bridge response during train passages using a monitoring and analysis platform that can be applied to multiple structures. This contributes to a better understanding of the bridges' true dynamic behaviour, associated challenges and their sensitivity to defects in the track and rolling stock.

BRIDGE MONITORING

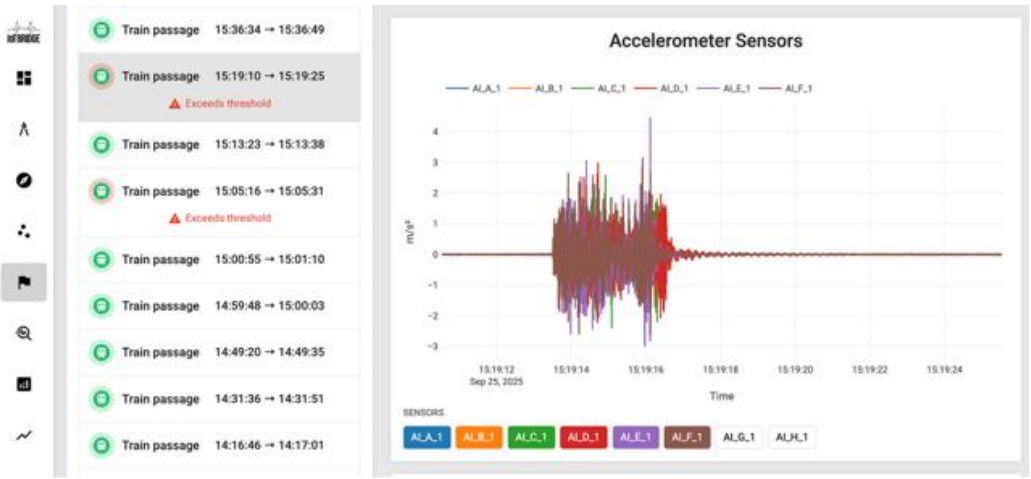
The Tajo–Segura Trasvase Bridge, located along the Madrid–Valencia line approximately a 1.5-hour drive from Madrid, has been instrumented with several sensors measuring, among other things, strains and vibrations. These sensors deliver real-time data from passing trains and the bridge's response. The bridge consists of two prestressed concrete box girders arranged in four simply supported spans, each approximately 30–35 metres long, with a total length of 135 metres. Two of the spans are instrumented to capture the structural response corresponding to span lengths of 30m and 35m respectively. The bridge is trafficked by various train types at speeds of up to over 300km/h. This bridge type is common in Spain but has been shown to face challenges related to dynamic effects and cracking. The measurement system generates large volumes of data, which are processed, analysed and made available through a monitoring platform developed by the Swedish company IoTBridge, in collaboration with KTH.

The project is supported by the Europe's Rail Joint Undertaking and its members.

Tajo-Segura Travase Bridge.

DATA ANALYSIS

IoTBridge is developing a smart and user-friendly platform that monitors bridges in real time. The system collects thousands of measurements every second from sensors and immediately analyses how the bridge reacts when trains pass. By using advanced algorithms, the platform can detect small changes that may indicate problems in the train, the track or the bridge itself. This makes it possible to identify defects early and increase safety across the entire railway system. The results from the project are expected to contribute to new recommendations for modelling train–track–bridge interaction under dynamic loading. Together with Europe's Rail project InBridge4EU, which aims to improve normative criteria for evaluating the dynamic performance of railway bridges, recommendations are also being developed for revisions of the Eurocodes. With updated criteria in regulations that reflect the bridges' real behaviour based on the tests carried out within Europe's Rail, future railway bridges can be designed more cost-effectively.



Train passages and measured accelerations.

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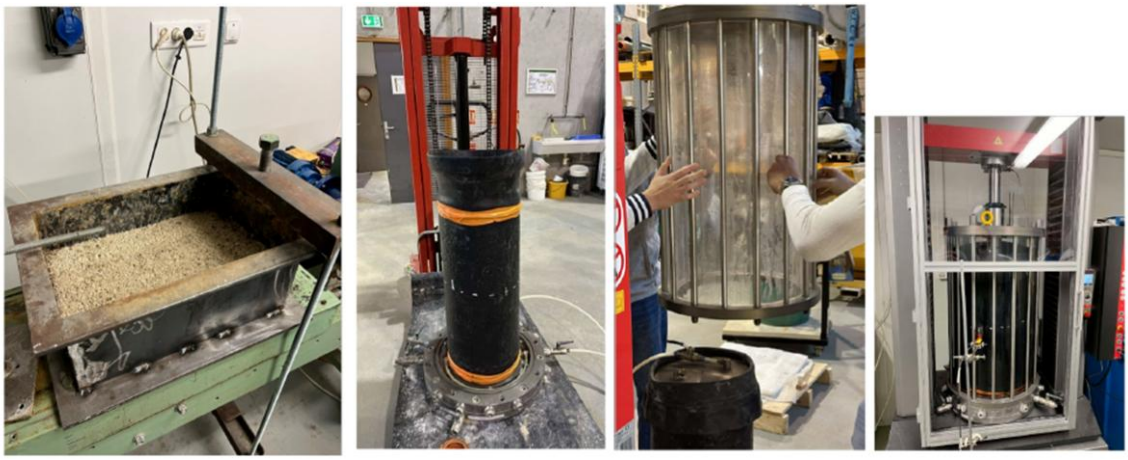
NUMERICAL SIMULATIONS FOR TRACK BED OPTIMISATION

SNCF Réseau are carrying out laboratory tests and numerical simulation with academic laboratory to estimate mechanical proprieties of sub-ballast layers. Estimating the cohesion and friction angle parameters of a granitic-type material composing the sub-ballast layers is essential to refine the input data for numerical simulations. Thanks to numerical simulations, we can estimate a range of target bearing capacity values at the top of the sub-ballast layer. The ultimate goal is to identify the types of geogrids that optimise the thickness of the foundation layers and guarantee a target bearing capacity at the top of the sub-ballast layer.



Shear box and triaxial test preformed on granitic material.

SCOUR RISK PREDICTIVE ARTIFICIAL INTELIGENCE (AI): ENHANCING THE SAFETY OF CIVIL STRUCTURES

SNCF Réseau manages one of Europe's largest rail networks, spanning 27,000 km of track and more than 130,000 civil structures such as bridges, viaducts and retaining walls. About 10,000 of these have foundations in aquatic environments, making them particularly vulnerable to flood-related damage in the context of climate change. Many of these assets are also over a century old, which adds to the challenge of ensuring their ongoing safety and reliability.

To improve infrastructure resilience and anticipate risks more effectively, SNCF Réseau has developed PLATIPUS (Projects for Analysis of At-Risk Heritage – Aquatic Substructures), a predictive maintenance tool powered by artificial intelligence and machine learning. Instead of relying solely on traditional preventive or reactive maintenance, PLATIPUS analyses large volumes of data, including structural characteristics, environmental context, flood history, climate variables and sound of infrastructures, to identify the most vulnerable structures and forecast potential hazards such as scour (foundation erosion) and submersion risks.

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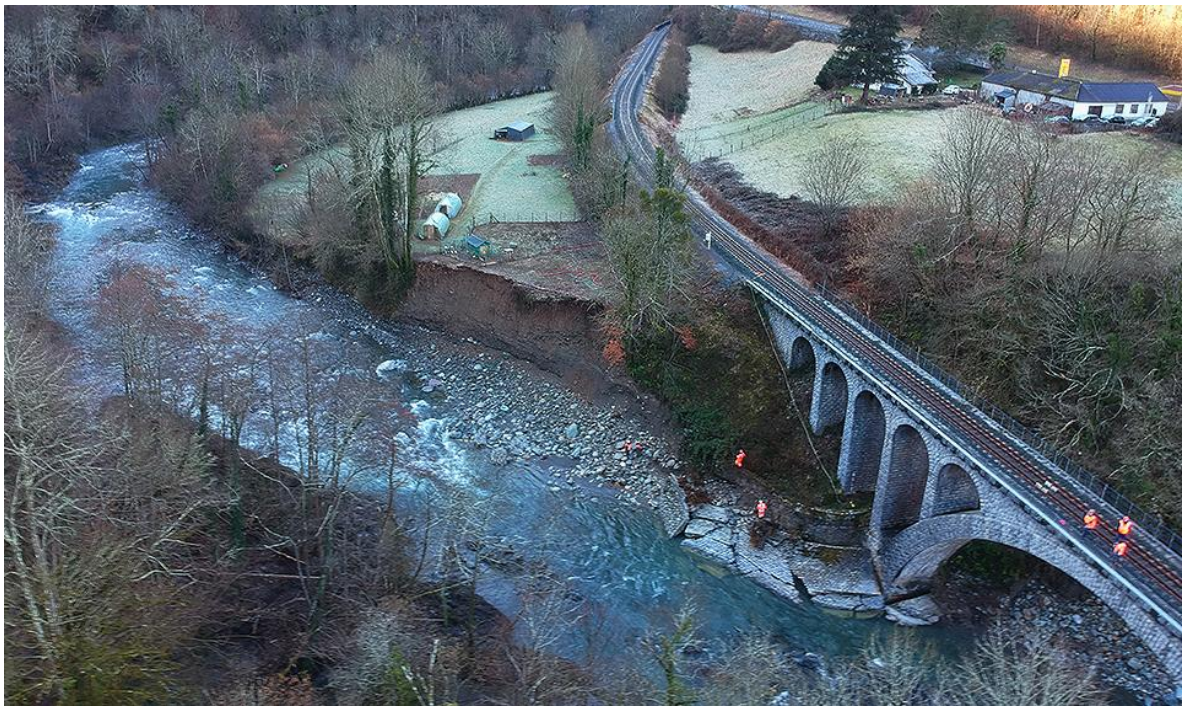

About 10,000 of France's civil structures have foundations in aquatic environments, making them particularly vulnerable to flood-related damage.

PLATIPUS PREDICTION TOOL

Key capabilities of the PLATIPUS system include:

- Risk identification by pinpointing structures most susceptible to failure.
- Risk prediction: estimating the likelihood of scour and inundation events.
- Real-time alerts: leveraging sensors and telemetry to trigger warnings when critical thresholds are reached.
- Prioritisation: helping target maintenance resources and investment where they're needed most.

Initial feasibility studies have shown strong performance, with predictive accuracy reaching up to 98%, and follow-up tests with international partners in Japan and the UK demonstrating robust results above 80% accuracy on their datasets. SNCF Réseau aims to scale the solution across all aquatic structures in its network, supporting safer operations and more efficient maintenance planning in the face of evolving climate risks.

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