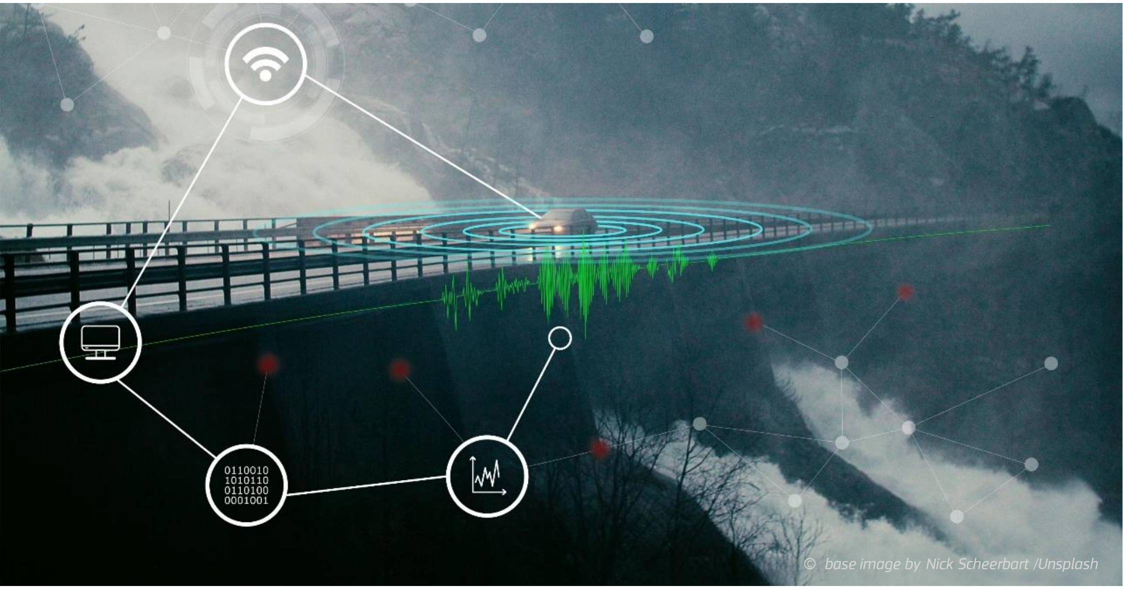
MITICA

MonItoring Transport Infrastructures with Connected and Automated Vehicles

JRC Exploratory Research Project 2020-2022



European Commission Joint Research Centre

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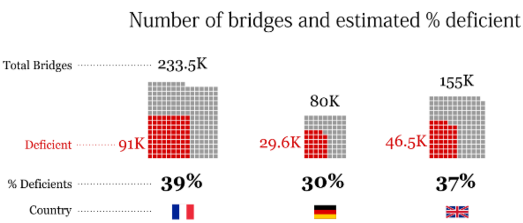
Introduction

Recent infrastructure assessment operations in Europe confirm that the EU transportation infrastructure (bridges, roads, railways) is ageing, with 30-40% of the existing bridge stock presenting deficiencies, 45% of the entire EU motorway network being built before 2001[1], while 35% of the EU railway bridges being above 100 years old[2].

As the ageing EU infrastructure is approaching its design life, investments in maintenance and retrofitting are warranted to ensure serviceability and safety.

Technological advances linked to structural monitoring and data processing are fast evolving. Innovative approaches are developed, striving towards the quantitative condition assessment of the existing infrastructure.



Structural Health Monitoring (SHM) campaigns can monitor the infrastructure integrity in real-time, detect potential damage and facilitate better informed decisions by civil infrastructure owners, local authorities, national agencies, and governments on taking refurbishment, retrofitting, upgrade, or replacement actions for the existing infrastructure.

Nonetheless, the extensive use of SHM application to the large EU bridge stock is still limited by the available resources. Mobile, fast and economic solutions are necessitated.

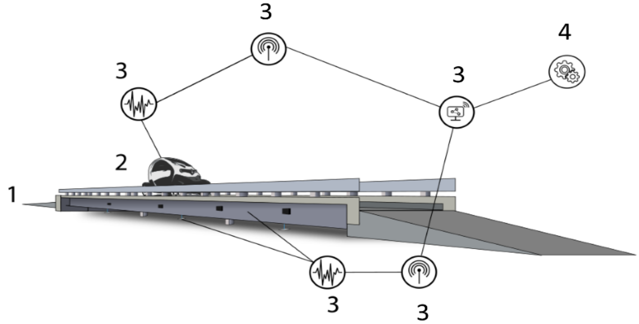
Morandi collapsed bridge in Genoa, Italy (14/08/2018)

[1]*BRIME 2001. Deliverable D14 Final Report. [www document]* *https://trimis.ec.europa.eu/sites/default/files/project/documents/brimerep.pdf*

[2]*Bell, B., Network Rail, 2007. Sustainable Bridges. Assessment for Future Traffic Demands and Longer Lives, WP1-02-T-040531-R-Deliverable D 1.2*

The MITICA Project

MonItoring Transport Infrastructures with Connected & Automated Vehicles



Inspired by technological developments on connected mobility, this project aims to contribute to the EU priority "*A Europe fit for the digital age*" by exploring synergies between connected vehicles and smart infrastructure components for the fast and mobile assessment of the existing bridge stock.

The above synergies can exploit the dual functionality of a passing vehicle as it both excites the infrastructure and records its response, offering a monitoring at the highest spatial resolution. These advantages will be assessed within a full-scale experimental campaign on a bridge-like structure under laboratory-controlled conditions. It is expected that the developed methodology will be equally useful in monitoring existing roads and railways.

The MITICA scientific concept is based on the following steps:

1. Experimental campaign - structural specimen set up.
2. Connected vehicles with mounted sensors.
3. Autonomous wireless sensors, signal acquisition, wireless transmission and data collection by a base station.
4. Data processing algorithms for Vehicle-to-Bridge Interaction (VBI) and indirect Structural Health Monitoring (iSHM).

It is envisioned that the above aims and objectives will support European policies related to vehicle data sharing and standardisation of communication protocols[1,2].

[1]*European Commission 2018. Europe on the move - Sustainable Mobility for Europe: safe, connected, and clean COM/2018/0293 final, Brussels.*

[2]*European Commission 2018. Europe on the move - On the road to automated mobility: An EU strategy for mobility of the future COM/2018/283 final, Brussels.*

Objectives

Towards Smart Infrastructure Monitoring with Integrated Connected & Automated Vehicles

- ❑ Full-scale experimental campaign on indirect Structural Health Monitoring

- ❑ Energy-autonomous wireless sensors


EUROPEAN COMMISSION

Brussels, 17.5.2018
COM(2018) 293 final

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COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS

On the road to automated mobility: An EU strategy for mobility of the future

- ❑ Support the development of European policies related to vehicle data sharing and standardisation of communication protocols

- ❑ Building up on expertise from multiple Institutional JRC Activities – *C2ART, SMARTBUILD, SPRINT, TRIMIS*

- ❑ Exploitation of cross-sectorial JRC expertise on Connected and Automated Vehicles combined with Civil Structures

- ❑ Involvement of external stakeholders

Experimental Campaign

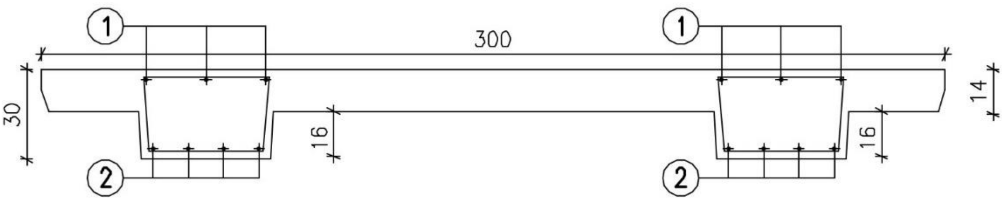
Structural Test Specimen for Drive-By Monitoring

The full-scale drive-by monitoring campaign will be conducted on a prefabricated reinforced concrete bridge-type platform placed at a dedicated testing site of the European Commission Joint Research Centre site in Ispra, Italy.

Geometrically, the bridge test specimen is 9 meters long and 3 meters wide.

It consists of a 14 cm thick flat deck enhanced with two trapezoidal down-stand beams (44 cm wide, 30 cm deep) running along the platform's length.

The testing area will comprise a road circuit for the vehicle access onto the bridge specimen, which is currently under preparation.



Section of the MITICA bridge test specimen

Connected Vehicles with Mounted Sensors

Inspired by Connected Mobility

Connected vehicles can provide a wealth of data in real-time, which can be particularly useful for the drive-by monitoring of the existing infrastructure.

Their applicability and usefulness can be reflected into a complementary or the main monitoring system.

To approximate connected vehicles, the MITICA experimental campaign relies on a customised vehicle with mounted wireless sensors.

Autonomous Sensors

Wireless Sensors Powered by Solar Panels

Power-autonomous wireless sensors are employed using solar panels attached to each wireless node.

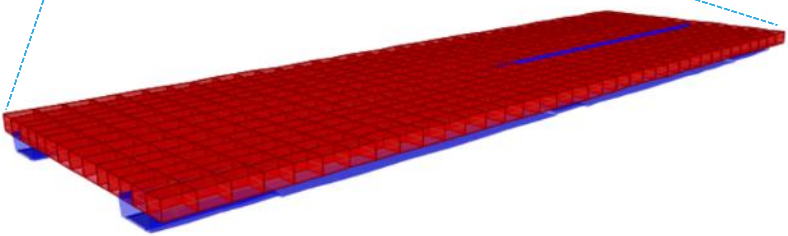
By exploiting the JRC expertise on such energy harvesting technologies (SMARTBUILD project), useful information can be obtained on power efficiency, wireless communication and data storage management.

The power-autonomous wireless sensor network comprise:

- Wireless sensors attached onto the vehicle – wireless sensors operations include: signal acquisition, data storage and processing;
- wireless transceivers for the wireless communication/data transmission between sensors and server; and
- a centralised base station/server that collects the recorded measurements from all sensors and allows for further data post-processing operations.

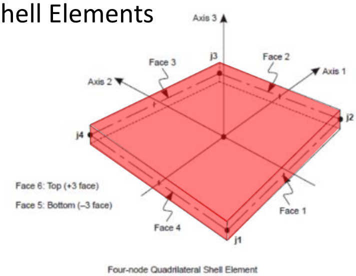
Finite Element Modelling

Structural Finite Element Modelling for Experimental Verification



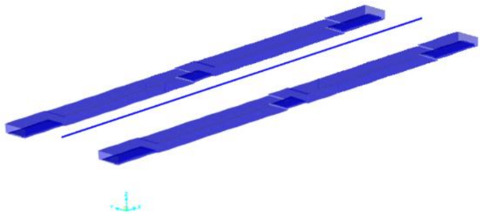
Deck simulation:

Shell Elements



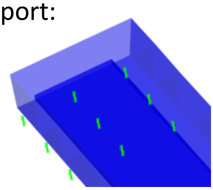
Down-stand Beams:

Beam Elements



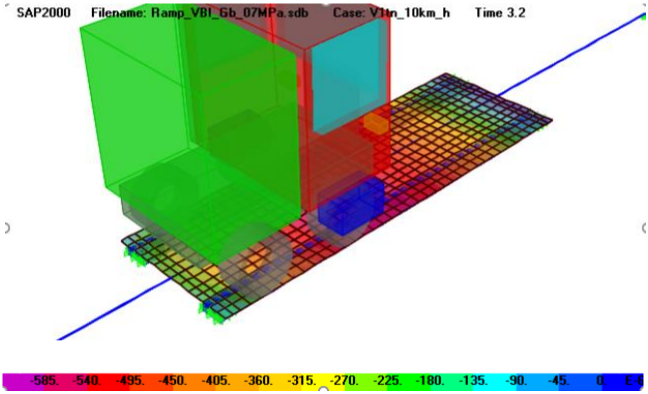
Structural Support:

Area Springs



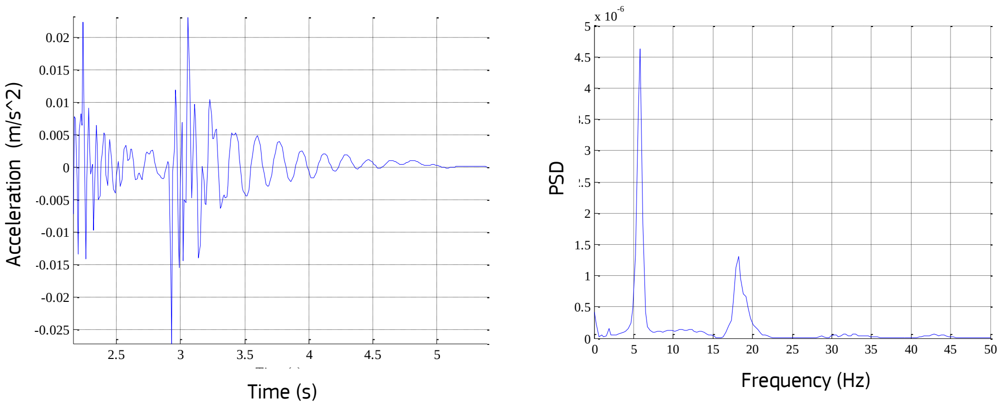
Finite Element Analysis

Dynamic Finite Element Analysis Under a Moving Vehicle



Dynamic Finite Element Analyses under a moving vehicle & acceleration recordings at the axle's location.

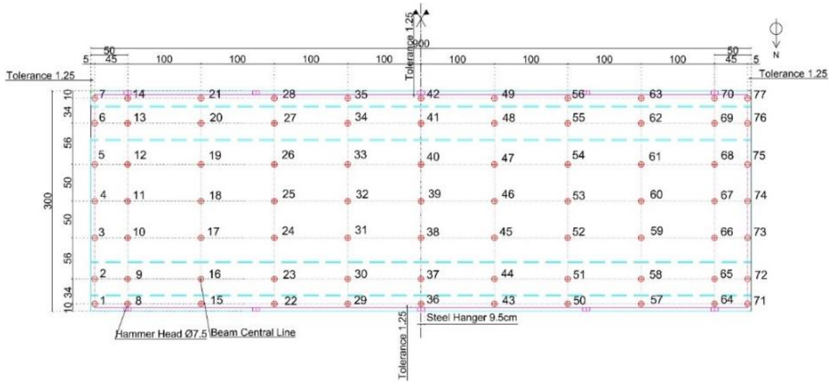
Scope: Identification of the inherent structural properties (i.e., modal properties) from the vehicle-recorded measurements under various vehicle speed levels, road surface irregularities and measurement noise.



Representation of simulated acceleration signals acquired from the front axle of a passing vehicle in time (left) and frequency (right)

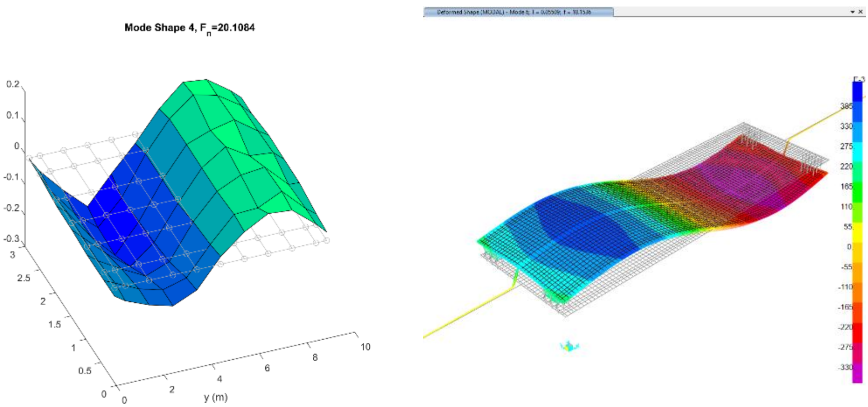
Preliminary Experimental Testing

Fast Hammer Impact Testing (FHIT) for Modal Identification of the Bridge



A preliminary experimental testing is conducted to determine the inherent bridge modal properties. This will be used as reference in the drive-by MITICA monitoring campaign with the scope to identify one of the two underlying systems in interaction (i.e. the vehicle and the bridge).
This tests comprises:

- Multi-Input-Single-Output Fast Hammer Impact Testing;
- Impulse excitation at 77 structural nodes;
- Structural acceleration responses recorded at a single location;
- Comparison of a wireless versus a wired sensor network.



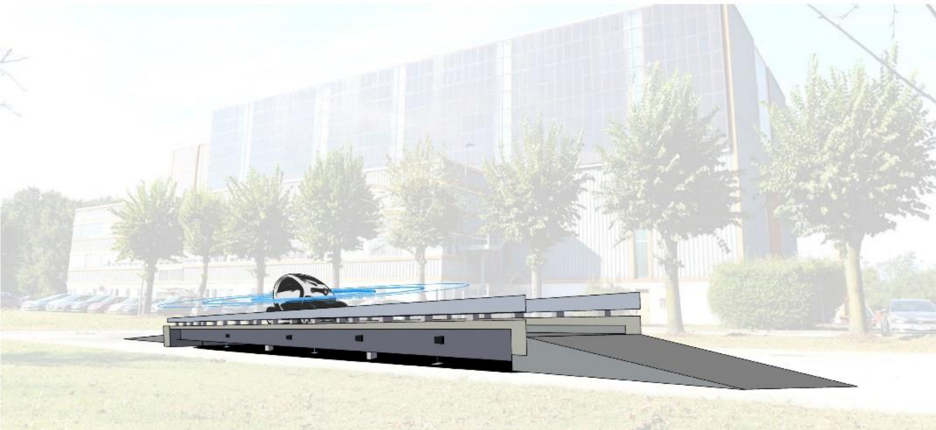
Mode shape estimation from experimental FHIT (left) compared against standard finite element eigen-analysis (right)

Signal Processing

Advanced Signal Processing Tools for Vehicle-Bridge Interaction Systems & Damage Detection

Considering the cutting-edge technology within the structural monitoring framework, indirect SHM algorithms will be developed based on advanced signal processing tools.

Building on prior knowledge on the dynamic properties of both the vehicle and the bridge, great advantages of the drive-by monitoring operations can be explored.



Acronyms, Definitions & European Commission JRC Projects

Acronyms

iSHM	Indirect Structural Health Monitoring
FE	Finite Element
SHM	Structural Health Monitoring
VBI	Vehicle to Bridge Interaction
V2I	Vehicle to Infrastructure

Definitions

Modal analysis (or eigen analysis) is a set of mathematical equations that enables the determination of the vibration characteristics of a mechanical structure or component that are associated with the movement of different parts of the structure under dynamic loading conditions.

Natural frequencies, mode shapes and damping ratios, termed as structural **modal properties,** are the inherent vibration characteristics of a mechanical structure.

Infrastructural monitoring operations relying on sensor-equipped vehicles that travel over an infrastructure component (bridge, road, railway) are typically termed in the literature as **indirect Structural Health Monitoring** (iSHM), **drive-by monitoring**, **vehicle-to-infrastructure** (V2I). When the infrastructure component is a bridge, the term **vehicle-to-bridge interaction** (VBI) is also used.

European Commission JRC Projects

MITICA - MonItoring Transport Infrastructures with Connected & Automated Vehicles

C2ART - Towards a Connected, Coordinated and Automated Road Transport system

SMARTBUILD - Smart Building Infrastructures

SPRINT - Cooperative Intelligent Transport Systems and vehicle cybersecurity

TRIMIS - Transport Research and Innovation Monitoring and Information System

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JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

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