C4R

Capacity for Rail

Implementation in new structures

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SEVENTH FRAMEWORK PROGRAMME

C4R
Capacity for Rail

Contents

I. **Identification** of monitoring needs

II. **Analysis** of Technologies Available in marketplace

III. **Selection** of Technologies

IV. **In-lab** tests

V. **Implementation** in SP1 prototypes at CEDEX Track Box

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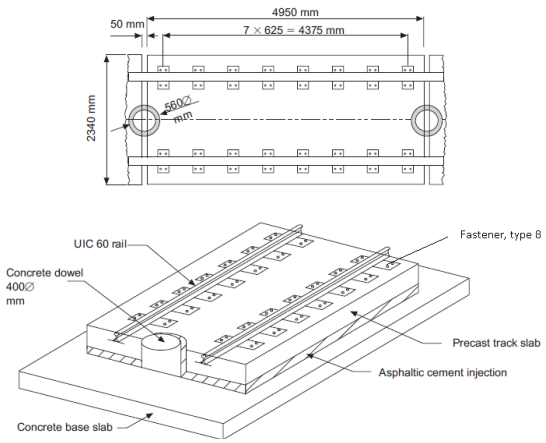
Identification of monitoring needs

- Goals
  - Development of a **monitoring system embedded** in the new concepts of slab track developed within C4R
  - Based on **technologies available in marketplace**
  - Features pursued:
    - ✓ **Low cost**
    - ✓ **Easy** and **quick** to **implement** during the construction of the infra
    - ✓ **Easy** or **none maintenance**



Shinkansen slab track system

FBB slab track system (Max Bögl)

Identification of monitoring needs

Requirements

- for the integrated monitoring system devices
  - ✓ Sensor nodes shall be **low-cost**
  - ✓ Sensor nodes shall be **energetically autonomous** (battery-free or energy harvesting methods for self-recharging)
  - ✓ Sensor nodes shall be **embedded** in the infrastructure elements (i.e. below some centimetres of concrete)

+

- for the Communications systems
  - ✓ **Wireless**
  - ✓ **Accuracy** and **precision**
  - ✓ Avoidance of **Interferences**

Both **MUST BE compatible**

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Analysis of market available technologies

- Study and analysis of wireless communication applications
  - ✓ Wi-Fi
  - ✓ Wi-MAX
  - ✓ GSM/GPRS
  - ✓ 3G
  - ✓ 4G
  - ✓ BLUETOOTH
  - ✓ ISM-band
  - ✓ IEEE 802.15.4
  - ✓ EPC 18000-6C
  - ✓ RFID active
  - ✓ **RFID passive**
- Specifications
  - ✓ **Range** of measurements
  - ✓ **Consumption**
  - ✓ Data rate
  - ✓ Response time

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Analysis of market available technologies

- Admissible levels for the studied features
  - ✓ **Range** of measurements: a short distance is good enough (--)
  - ✓ Data rate: Not continuos monitoring a low data rate is good enough as only few bytes (-)
  - ✓ **Consumption:** as lower as possible (---)
  - ✓ Response time: not a major constraint (--)
- Comparison

	Wi-Fi	Wi-MAX	Mobile	BLE	IEEE802.15.4g	Passive RFID
Range	-	+++	+++	--	++	---
Data rate	+++	+++	+++	+	+	-
Consumption	++	+++	+++	-	-	---
Response time	++	++	++	+	+	---

- +++ Very high value (of the feature)
- ++ High value (of the feature)
- + Normal value (of the feature)
- - Low value (of the feature)
- -- Very low value (of the feature)
- --- Ultra low value (of the feature)

To avoid **interference** with railway infrastruture communication, **reading distance** in RFID should be kept **below 12 meters**

SEVENTH FRAMEWORK PROGRAMME

WP 4.3. Implementation in new structures

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Passive RFID (battery free)

- Limited read range
- Discrete measures
- Able to be embedded in the concrete
- Low cost

Research and demonstration within C4R

Research but not demonstration within C4R "Vision 2050"

Active RFID (battery)

- Higher read range
- Ability for continuous monitoring (e.g. accelerations)
- Medium cost

Rechargeable battery

- Able to be embedded in the concrete

Non-rechargeable battery

- In a plug&play monitoring box

Energy harvesting

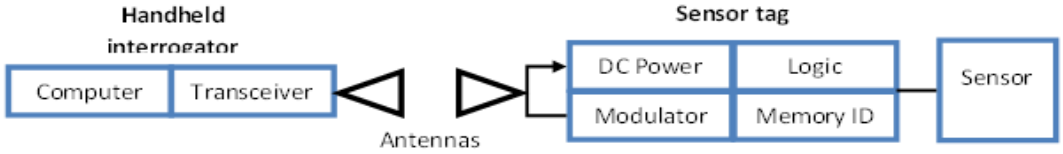
- Inductive charging with electromagnetic-fields already existing in the railway track

Tag Antenna

Tag Antenna

Selection of existing technology: Passive RFID technology

- Limitations of Passive RFID technology
  - ✓ Do **not** allow **continuous monitoring → discrete values** for record parameters
  - ✓ **Not all devices or sensors** are **compatible** with **RFID** communications → research on relevant sensors
  - ✓ **Interferences** need to be taken into account



- Compatible sensors with passive RFID
  - **Needed** of obtaining **relevant parameters** for **Structural Health analysis**
    - ✓ **Accelerometers (regarding modal analysis) are not possible** – they requires continuous or longer times of monitoring
    - ✓ **Other critical parameters** must be **considered: strains, moisture, temperatures…**

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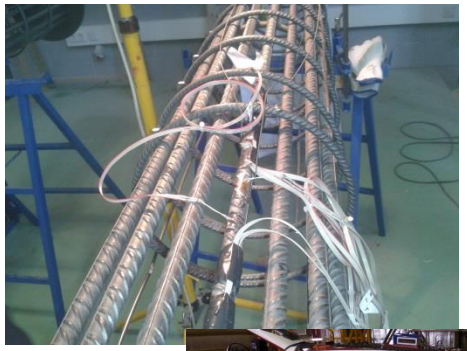
Market available RFID technology and strain gauges

- Strain Gauges
  - **Strain** measurements
  - **Widely spread** in industry
  - High level of **reliability** and **accuracy**
  - Great **number of** different **applications**

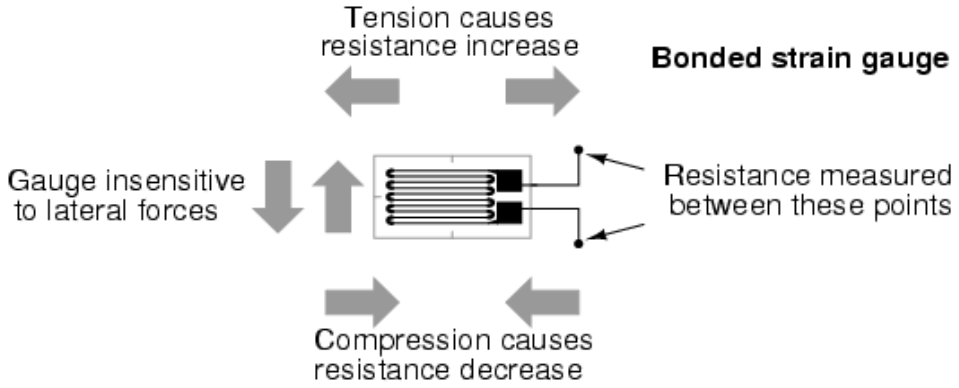


Structural engineering

Aeronautical industry

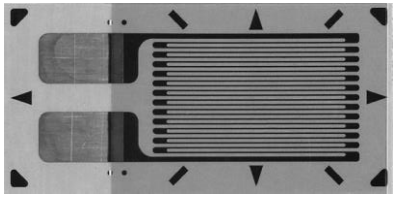
Car industry

- Operating principles

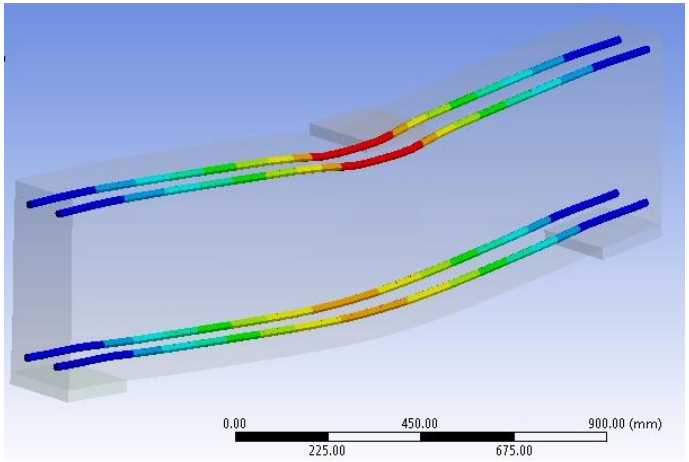


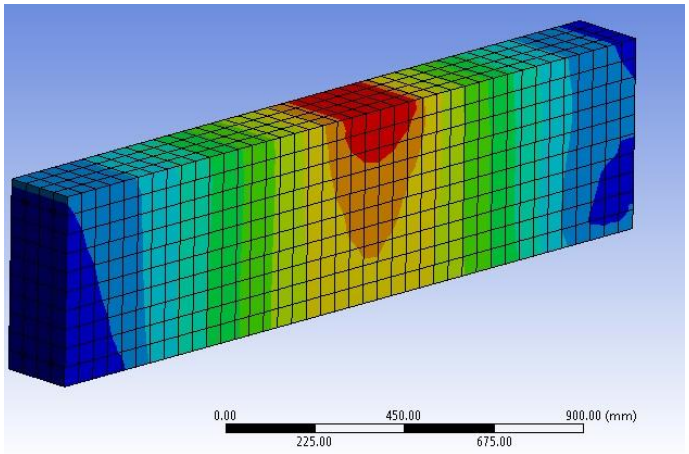
Market available RFID technology and strain gauges

- Strain Gauges
  - **Measurements application**
    - ✓ Strain/deformation in the reinforcement bars of the concrete slab track



From the strain determination in the reinforcement bars and through the use of FEM models it is possible to identify the state of stress in a slab or in a beam.





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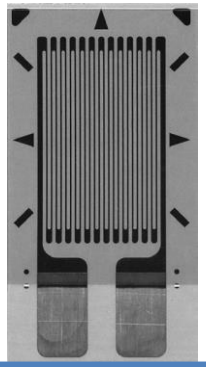
Market available RFID technology and strain gauges

- RFID Strain Gauges Restrictions
  - Needed of Voltmeter to read results → Vmeter RFID
  - Can be embedded in a concrete block
  - Connection between strain gauges and voltmeter are required
  - Wireless communication system to send results is a prescription of the system



- Price: 13,50 € (>25 units)

- Vmeter-DCLV10
- Low voltage DC metering
- Voltage range: 0V to 1.5V
- Voltage resolution: from 1.5mV (Gain=1) to 1.5µV (Gain=1000)
- Price: 10.11€ (>500 units)

- Price: 3,00 € (>30 units)

Material cost less than 35 € /Passive tag

Development of the sustainable monitoring system based on RFID technology

- IN-LAB TESTS

A number of in-lab test were performed in order to study the behaviour and performance of passive RFID in real environment

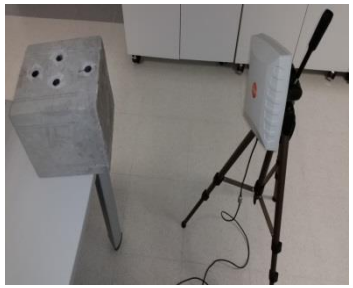
- Objective of tests:
  - **Analysis of signal attenuation:** due to concrete, steel and PVC coating
  - **Different technologies of antennae:** fixed and handheld.
  - **Comparison** with active RFID

- Parameters analysed
  - **Power** of antenna
  - **Thickness** of **concrete**
  - **Detection distance**
  - Maximum **reading distance**
  - **Influence of PVC coating** and **steel**

IN-LAB test results

- Attenuation signal analysis
  - ✓ Different concrete thickness
  - ✓ Possible steel interferences
  - ✓ PVC coating for RFID sensor



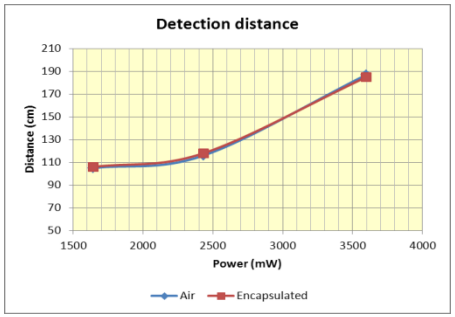


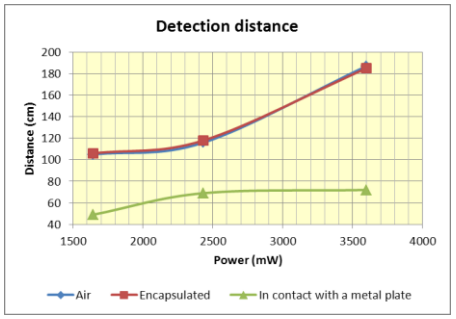
Title

IN-LAB test results

- 1ST CAMPAIGN

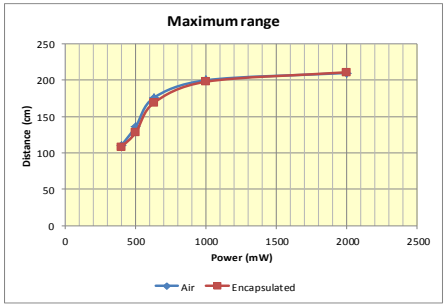
Assessment of the effect of
- Encapsulation
- Steel contact

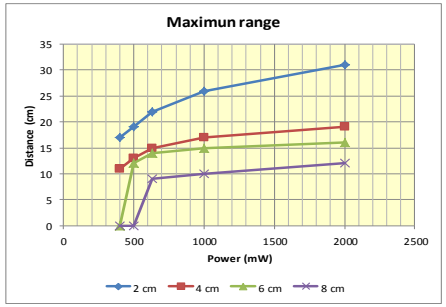




- 2ND CAMPAIGN

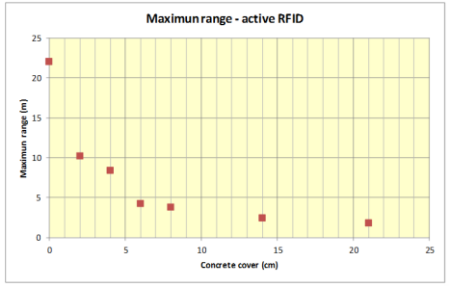
Analysis of maximum range of measurements
- In encapsulation environment
- Different thicknesses of concrete





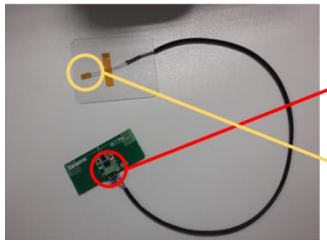
- 3RD CAMPAIGN

Contrast test to compare RFID active vs. RFID passive

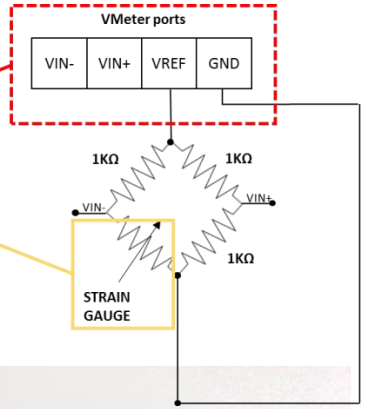


Implementation of the monitoring system in new structures

- Assembly of system



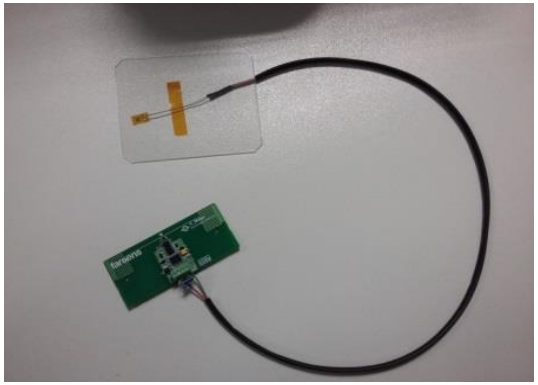
Vmeter + Wheastone Bridge with Strain Gage



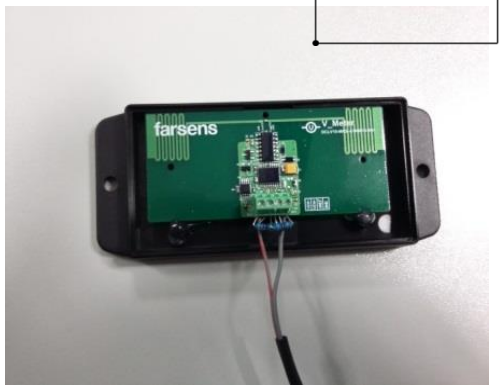
$$\epsilon = \frac{\Delta R/R}{\text{Gauge factor}}$$

$$\Delta R = \frac{4RV_m}{V_R - 2V_m}$$

Where $Vm := V_{IN-} - V_{IN+}$



Vmeter + Wheastone Bridge with Strain Gauge



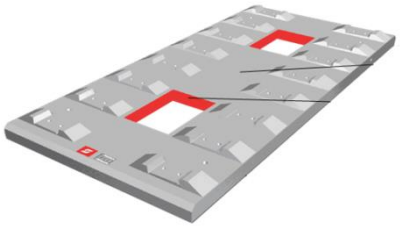
Encapsulation

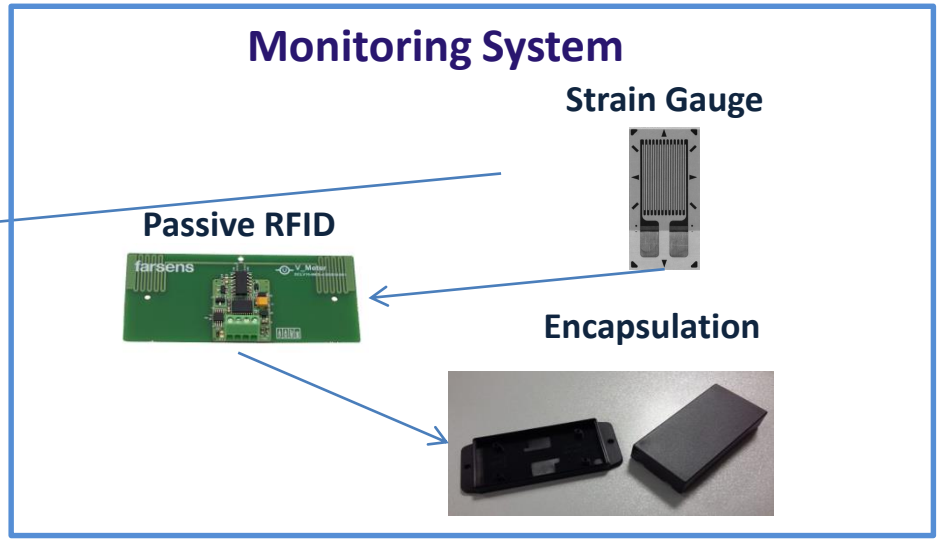
Prototype and labelling

Implementation of the monitoring system in new structures

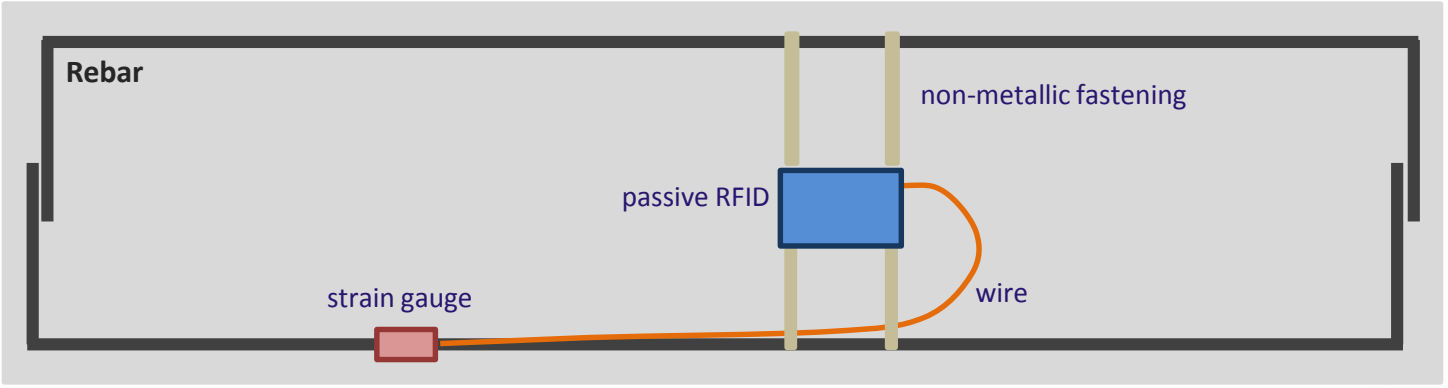
- Assembly of system

Prototypes SP1



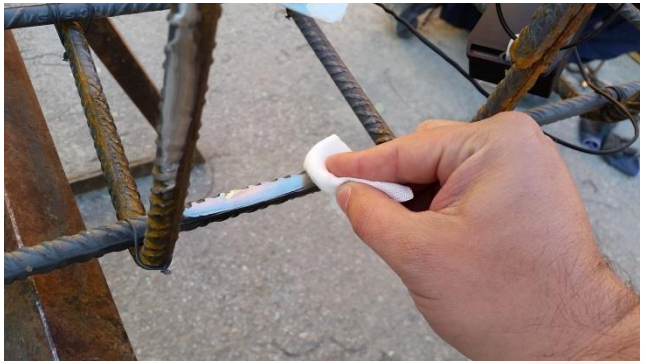


Reinforced Concrete Element



Implementation of the monitoring system in new structures SP1-W11

- 3MB and L-Track prototypes



Implementation of the monitoring system in new structures SP1-W11

- 3MB prototype

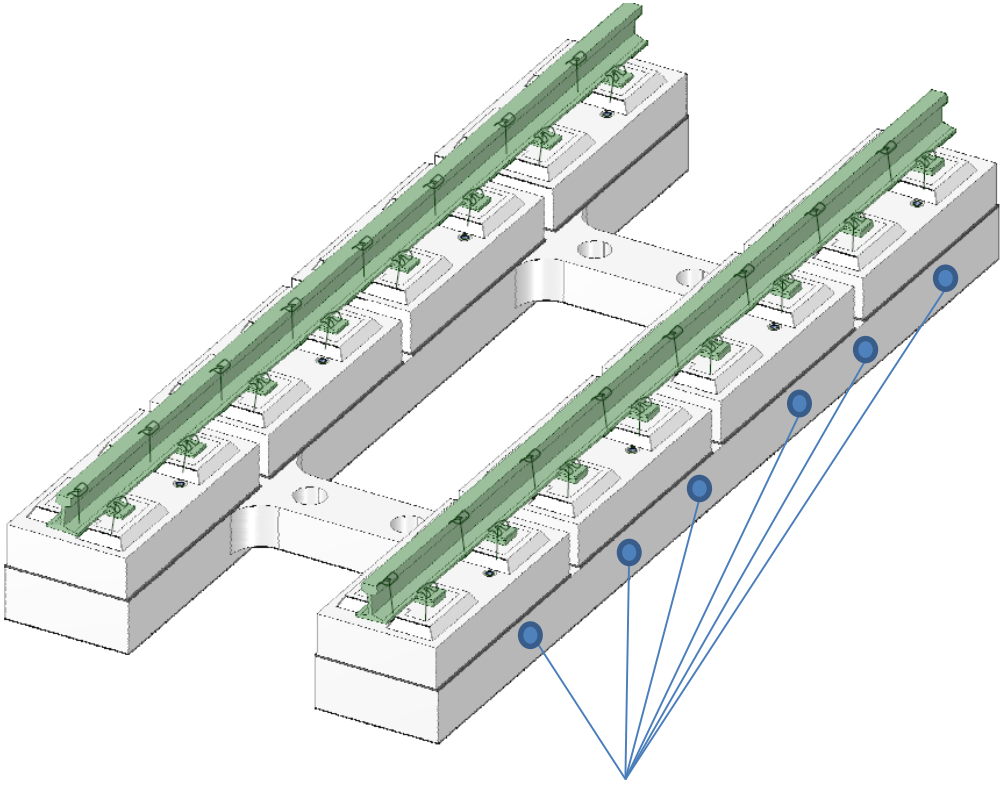



Implementation of the monitoring system in new structures SP1-W11

- **3MB prototype → installation completed**

Deployment at real pilot at CEDEX Track Box laboratory (Madrid, Spain)

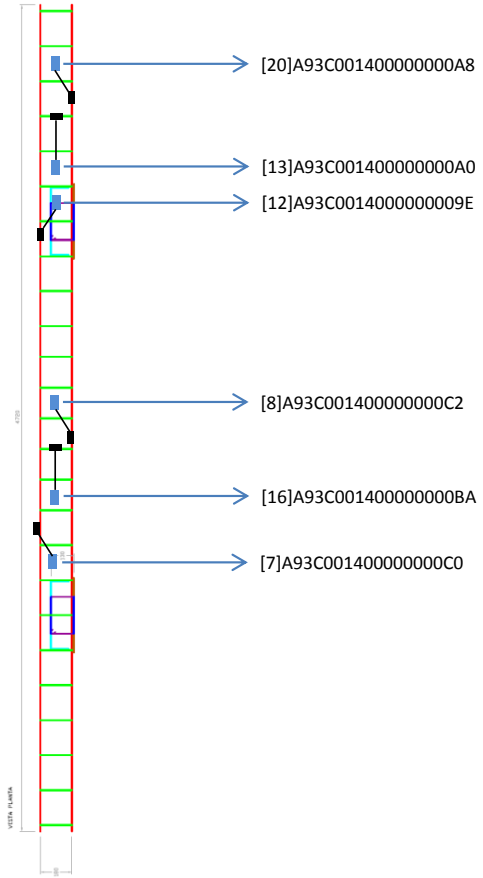
3MB slab track system prototype



Installation of the monitoring system

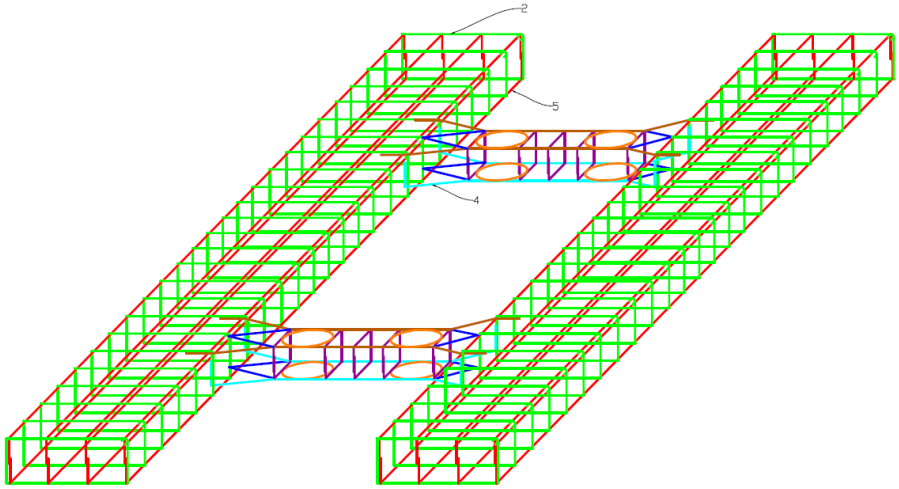
- Specific location of monitoring system in reinforcement bars scheme

3MB slab track system prototype



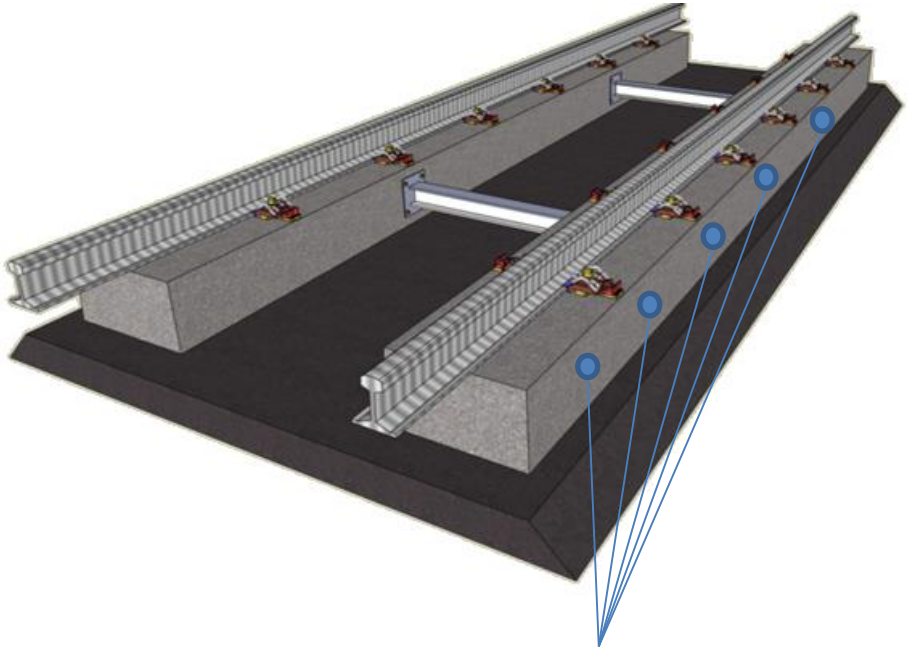
RFID Antenna

Strain Gauge

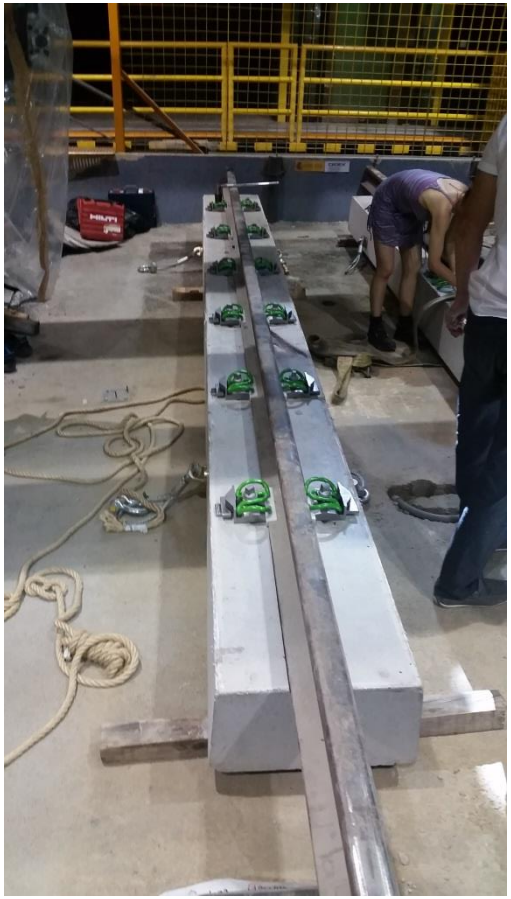


Deployment at real pilot at CEDEX Track Box laboratory (Madrid, Spain)

L-Track slab track system prototype

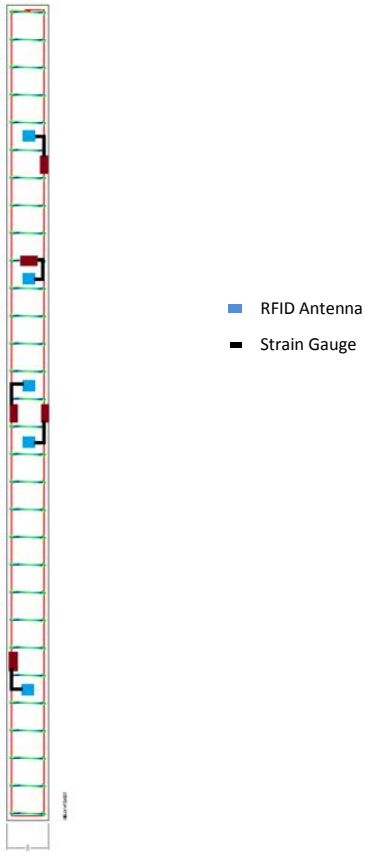


Installation of the monitoring system



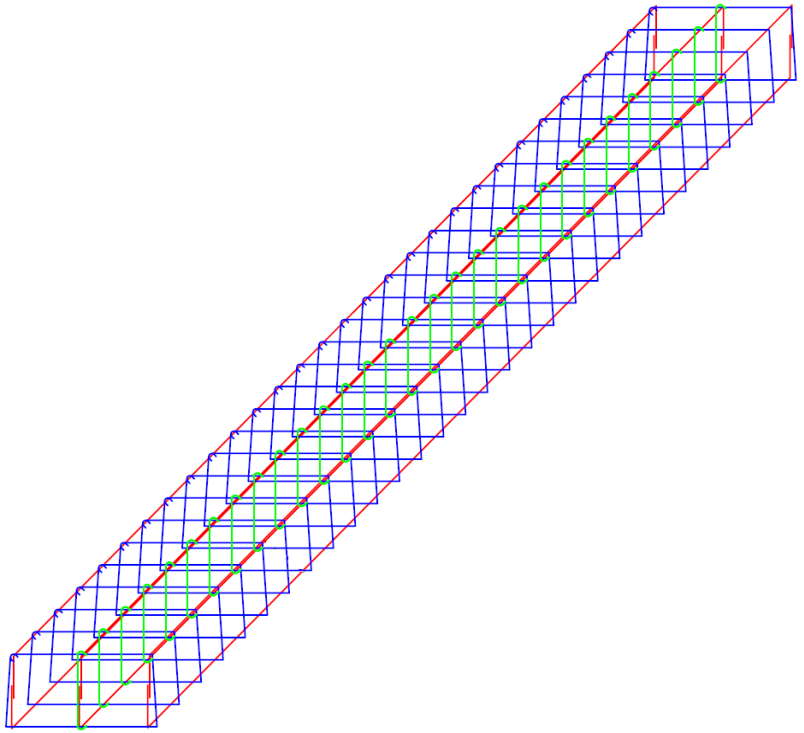
- Specific location of monitoring system in reinforcement bars scheme

L-Track slab track system prototype



RFID Antenna

Strain Gauge



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Performance test at real pilot at CEDEX Track Box laboratory (Madrid, Spain)

Handheld reader

Results

[20]A93C001400000000C2

[20]A93C001400000000BA

[20]A93C001400000000C0

SEVENTH FRAMEWORK PROGRAMME

Conclusions

- Results from tests performed on the prototypes from SP1 open the door to several and potential possibilities for the monitoring of slab tracks via RFID tags.
- RFID readers could be used to recover live data on the structural health analysis of different elements in the track with little added cost, saving significant amount of work and possession time of the track.
- More advanced RFID system (e.g. active tags) could be used to implement continuous monitoring and complex data gathering systems through the use of accelerometers or another measurement devices.

Thank you for your kind attention

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