C4R

Capacity for Rail

Towards an affordable, resilient, innovative and high-capacity European Railway System for 2030/2050

Demonstration of new monitoring techniques

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Deliverable 43.2

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- ACCIONA

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Executive Summary

This Deliverable D4.3.2 presents the results of the research carried out in task 4.3.4 of SP4 Advanced Monitoring - WP4.3 Implementation in new structures.

The aim of this deliverable is to describe the specific design, installation process, testing protocol and test results from the monitoring system devised in previous tasks (and described in D4.3.1). Said system has been installed in the demonstrators for the new infrastructure concepts developed in SP1, which shall also be thoroughly described in the document.

Based on the RFID sensor technology selected taking into account the studies developed in previous WP4.3 tasks, two monitoring systems were devised for the two developed concepts in order to prove the concept of RFID based monitoring and provide additional structural monitoring data to SP1.

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Abbreviations and acronyms

Abbreviation / Accronym	Description
RFID	Radio Frequency Identification
3MB	Moulded Multi Modular Block

1 Background

Today the availability of rail infrastructure is strongly influenced by the age and the local conditions, such as ground conditions, type of construction, and the local load. These factors will affect the life expectancy as well as the required maintenance.

Currently, monitoring systems are used in the railway sector by default only in certain singular locations. Other systems are in sue in just a few cases an then track or other systems are monitored by very specialised, - mostly expensive – applications. These few systems are usually intended as stand-alone solutions only, and specifically constructed for each individual case and region. An additional benefit is not given.

In order to meet the necessary criteria for the railway RAMS, the Advanced Monitoring Systems can help considerably.

WP4.3 will work in two directions:

- Establish a comprehensive monitoring strategy
- Use of sensor form other industries in high units produced
- The original monitoring equipment as part of the design solution
- A self-sufficient energy supply of the monitoring system.

This concept is absolutely unique and represents a major step forward towards a modern, cost-effective railway.

2 Objectives

The general objective of this deliverable is to describe the designed monitoring systems integrated in the new infrastructure elements developed in SP1, document the applied installation process and analyse the monitoring data recovered during the demonstration tests. There are several specific objectives to be achieved:

1. To describe the monitoring systems implemented in the SP1 concept demonstrators.
2. To prove the feasibility of installation and operation of the sensors that constitute the monitoring system.
3. To document any interferences and issues detected during the installation and testing.
4. To analyse the monitoring data recovered during the concept demonstration.

This deliverable has been structured in sections in line with the previous objectives. Therefore, Section 3 describes thoroughly the novel slab track concepts developed in SP1, Section 4 describes the design and installation procedure for the integrated monitoring systems in both concepts, Section 5 focuses on the description of encountered difficulties, and Section 6 analyses the recovered monitoring data.

3 Novel slab track concepts

As part of SP1, the task of WP1.1 was to develop two novel track concepts based on the slab track principles. To that effect, two colaborative brainstorming sessions took place in SYSTRA's premises during 2014.

As a result of these sessions, several conceptual designs were created and evaluated, their advantages, disadvantages and main features discussed, and two concepts were selected for further development.

In the first months of 2015 and as a result of the work done in previous tasks of WP4.3, critical defficiencies detected in the concepts required the celebration of additional colaborative workshops in order to rework the selected concepts.

Finally, in the second half of 2016, the reworked concepts were designed from a structural (both static and dynamic) point of view, and demonstrators were built for testing in the CEDEX track box facilities in Madrid

The following paragraphs describe the final design of the two developed slab track concepts.

3.1 3MB: Moulded Multi-Modular Block system

3.1.1 System description

The 3MB system is based on the concept of multiple-level modularity and strives to achieve fast and easy maintainability through the use of easily replaceable, precast components.

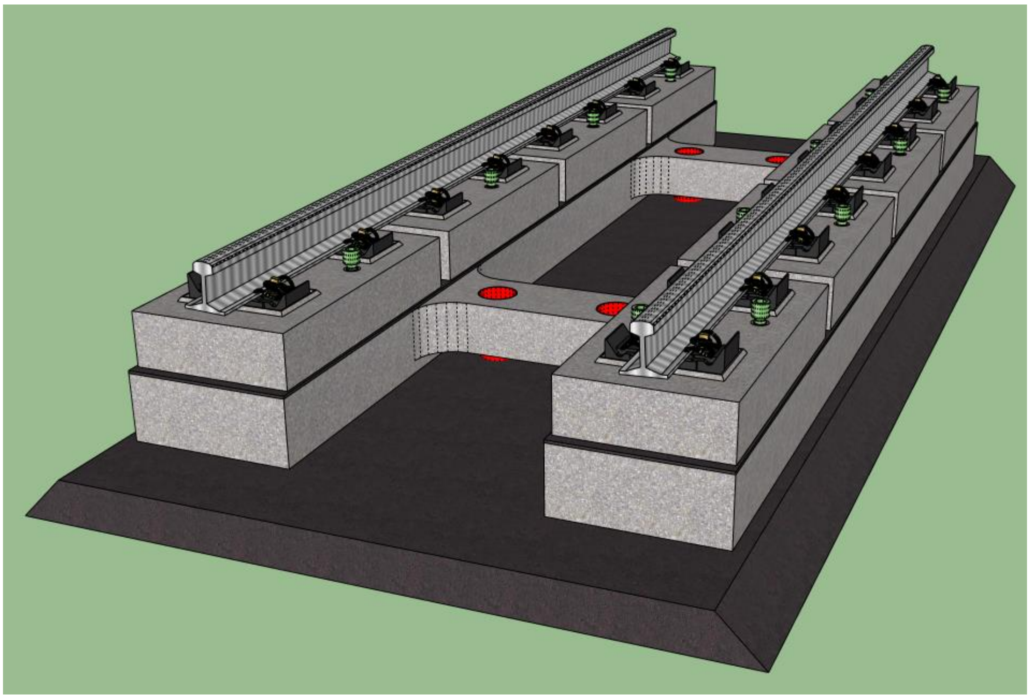


Fig 1: 3MB system

The system is composed of 4,80 m long modules, each comprising the following elements:

3.1.1.1 Base slab

The base slab is composed of two longitudinal 600 x 250 x 4780 mm reinforced concrete beams connected by two transversal beams with a 300 x 200 cross section and R150 mm concave chamfers in the intersections with the longitudinal beams.

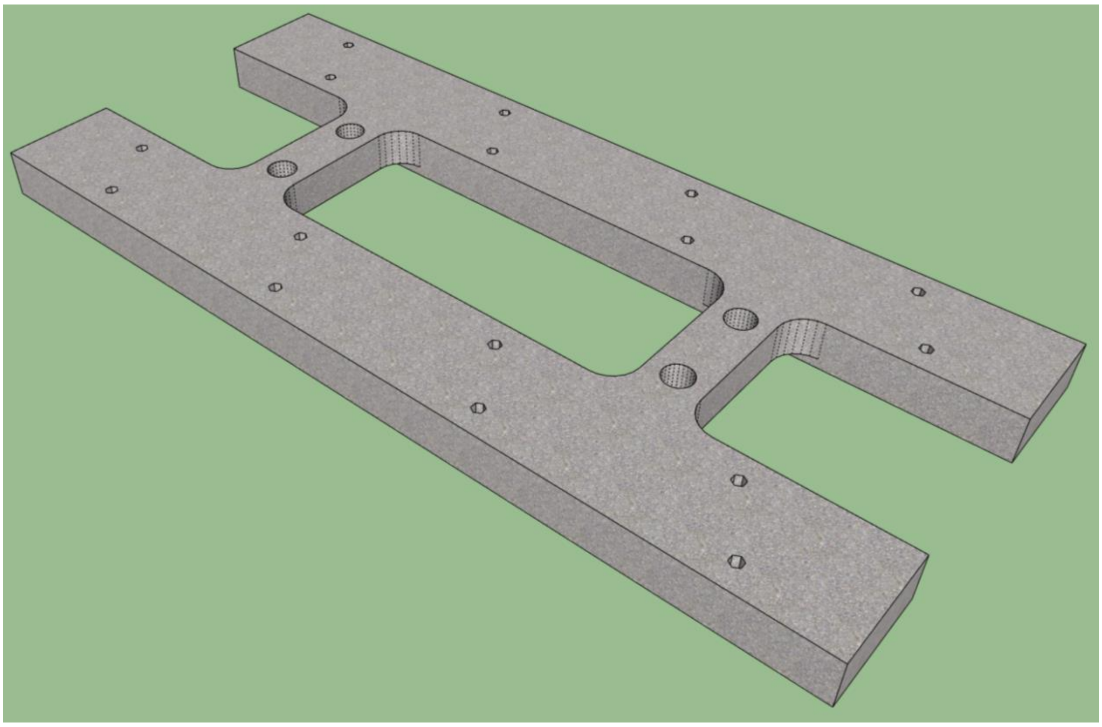


Fig 2: Base slab

Additionally, the transversal beams present R75 mm cylindrical through holes for in-situ connection with the sub-base where needed.

3.1.1.2 Elastomeric layer

Two 10 mm thick TPV+EVA elastomeric strips cover the surface of the slab, providing extra vibration attenuation for the system and preventing the hammering of the moulded blocks against the base slab.

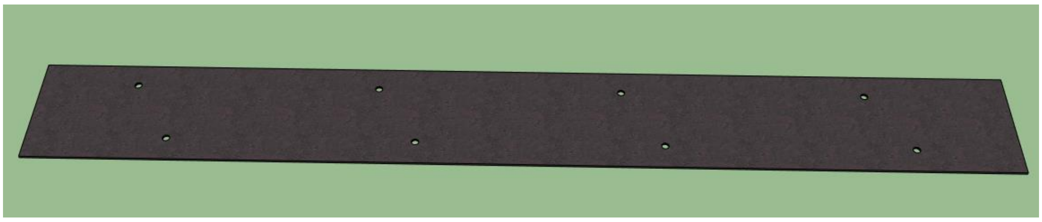


Fig 3: Elastomeric strip

The mats present R18 mm cylindrical through holes to allow the passage of the steel pin system connecting moulded blocks and base slab.

3.1.1.3 Moulded blocks

Eight precast concrete blocks, four on each longitudinal beam of the base slab, provide support for the fastening system and rail.

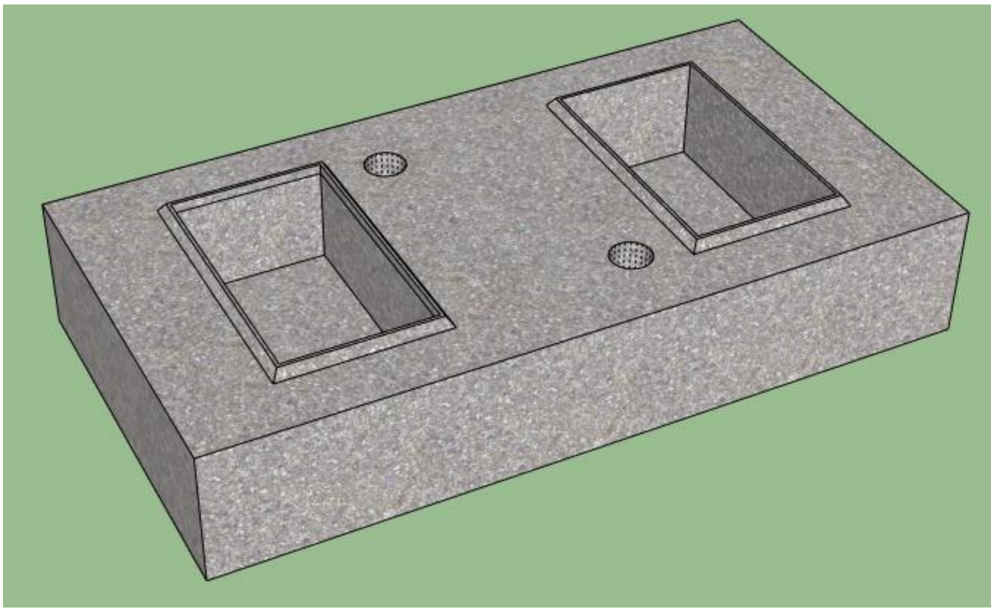


Fig 4: Moulded precast blocks

The blocks are parallelepipeds 200 mm high, 1120 mm long and 580 mm wide, and present in their top face two 380 x 220 x 140 mm cavities for the levelling adjustment and installation of fasteners, as well as two R30 mm cylindrical through holes to accommodate the steel pin connection to the base slab

3.1.1.4 Steel pin connecting system

In order to restrain the moulded blocks horizontally while allowing unrestrained vertical movement, a double steel piston system has been devised.

The system is devised so that the piston is fixed to the base slab while the cylinder is fixed to the through holes in the block, thus allowing the block to move parallel to the piston axis but constraining all other movement.

Each block is restrained by two non-coaxial steel connectors, thus preventing unwanted rotation around the piston axis.

Each of the two steel connectors (or “pins”) are comprised of the following elements:

- A 100 mm long M36 hexagonal steel nut, embedded in the base slab by means of a soldered R40 mm flat washer 8 mm thick
- A 350 mm long M36 partially threaded steel bolt, presenting 100 mm of thread
- A 200 mm long R21 steel tube, 3,6 mm thick, Teflon-coated in the inner surface and connected to the moulded block by means of mortar poured *in situ* between the tube and the cylindrical through holes in the block

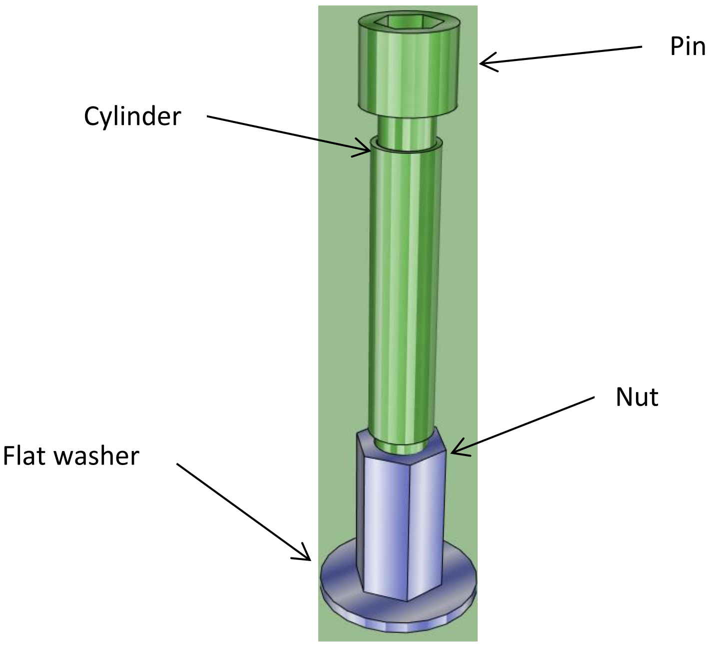


Fig 5: Steel pins

3.1.1.5 Fastening system

The 3MB slab track uses System DFF21 from Vossloh as rail fastening system, connected to the moulded blocks through plastic dowels embedded in mortar, poured *in situ* in the rectangular block cavities prepared to that effect.

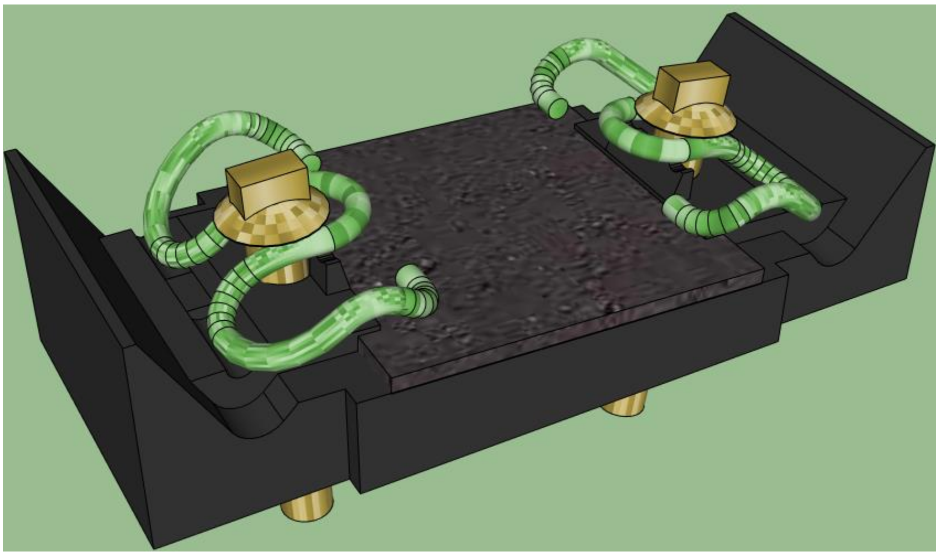


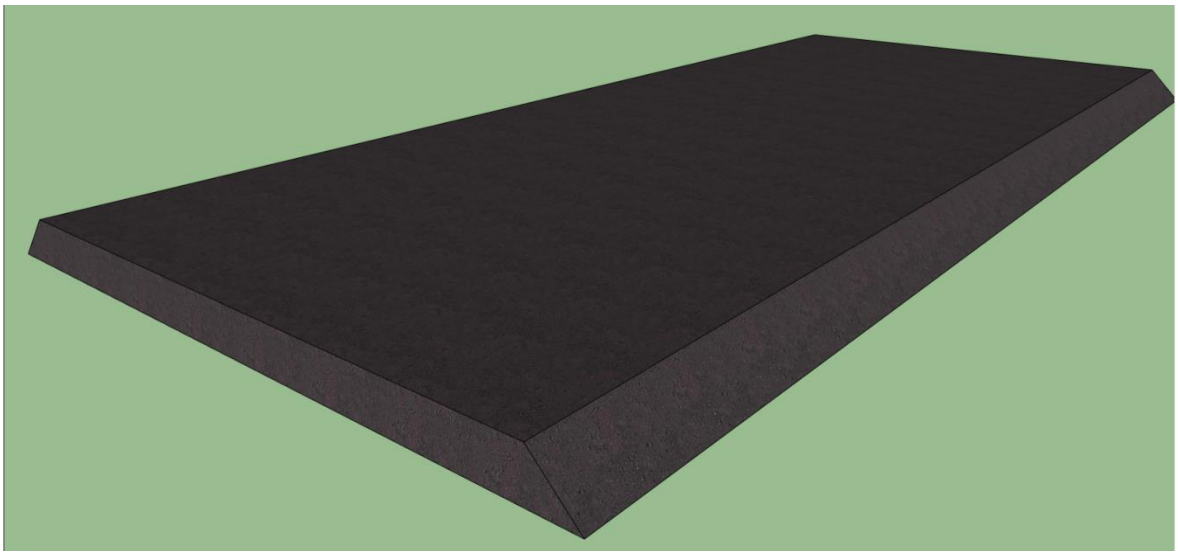
Fig 6: DFF21 Fastening system

3.1.2 System assembly

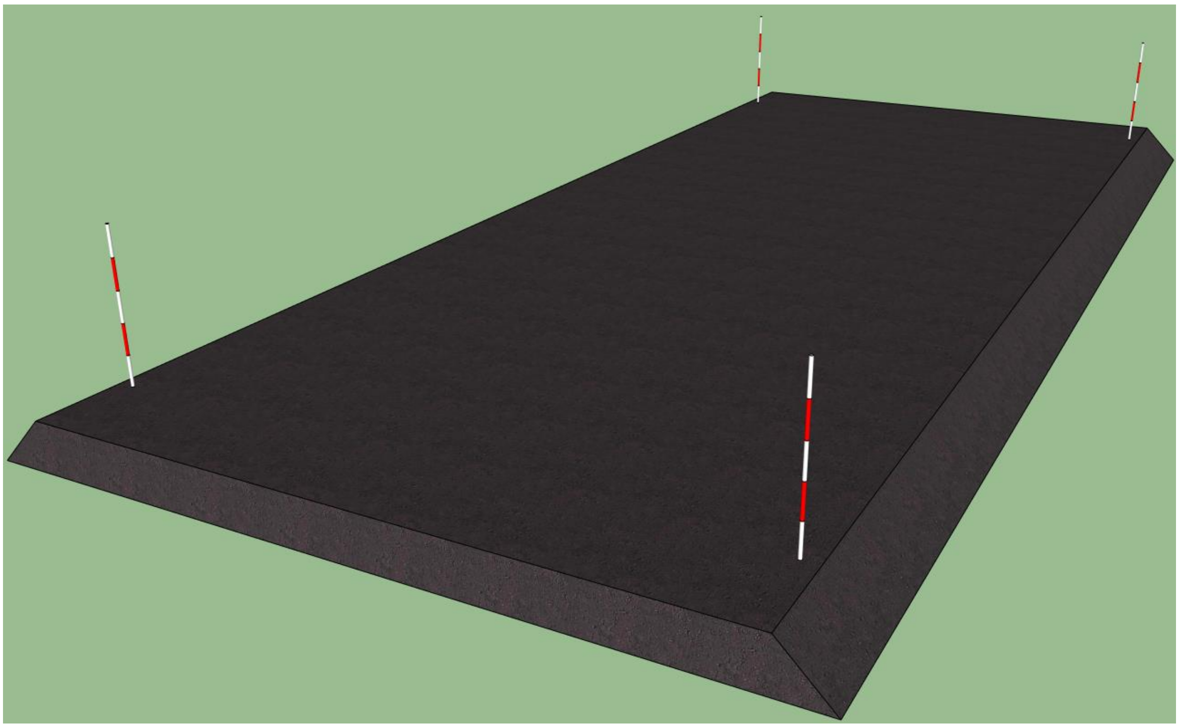
Given that both base slab and moulded blocks are precast, the assembly procedure strives to be fast and easy, allowing for part replacement with minimum disturbance.

The assembly process is composed of the following steps:

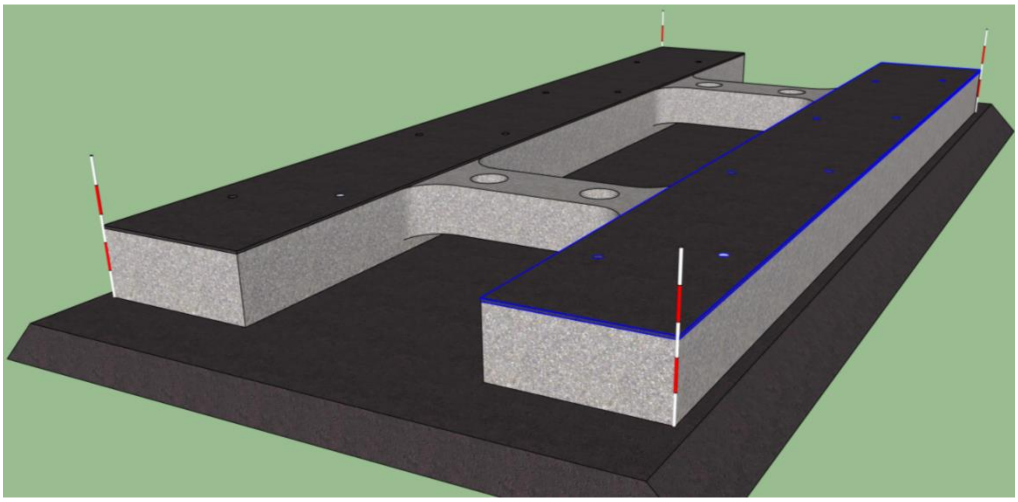
1. Bituminous sublayer application:



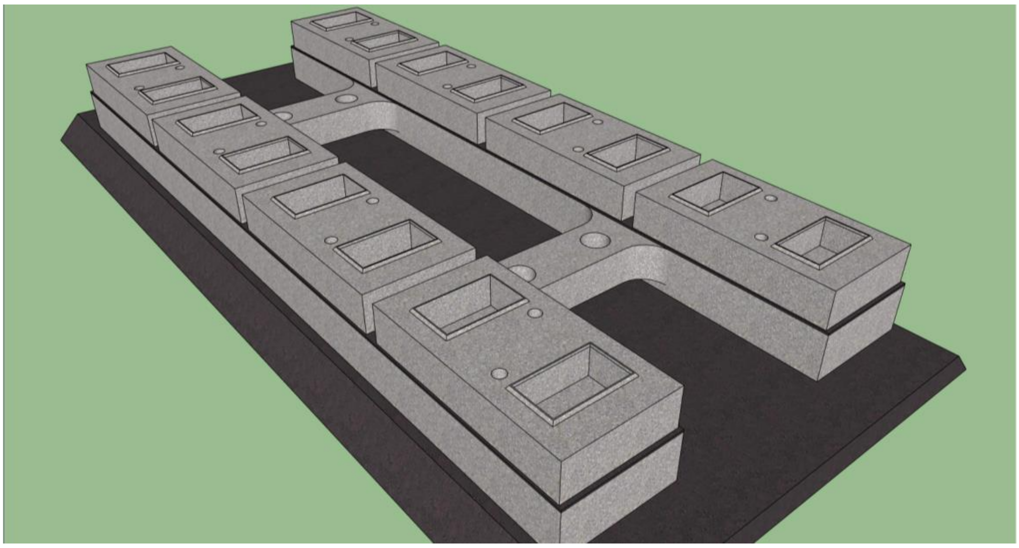
2. Rough topographic location of base slabs



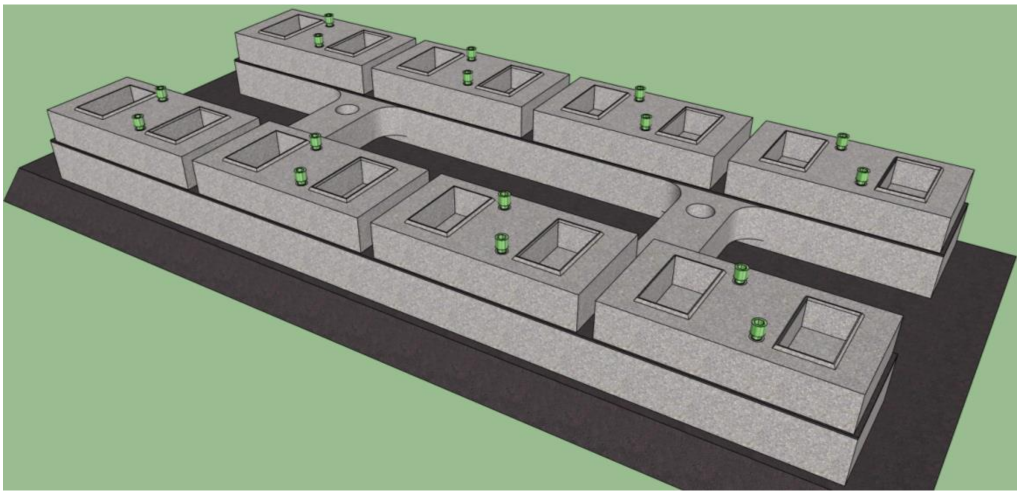
3. Base slab (with premounted elastomeric strips) positioning:



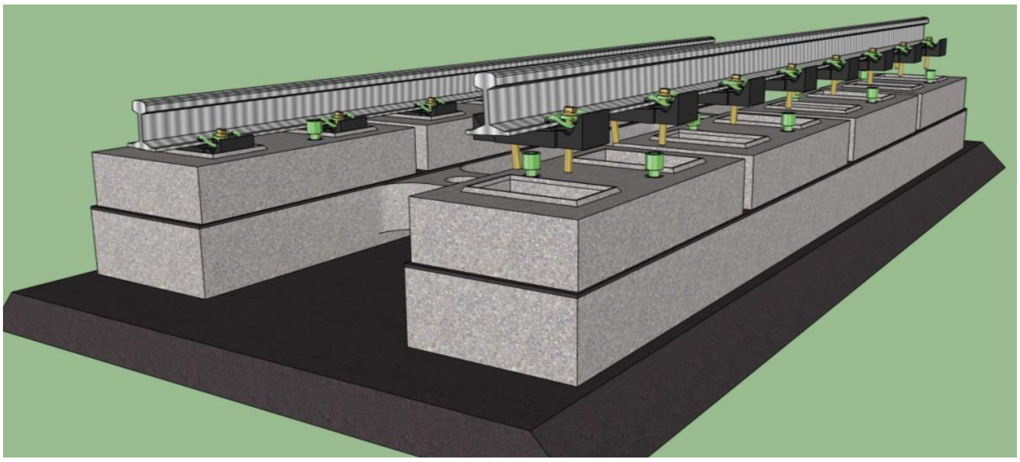
4. Moulded block positioning



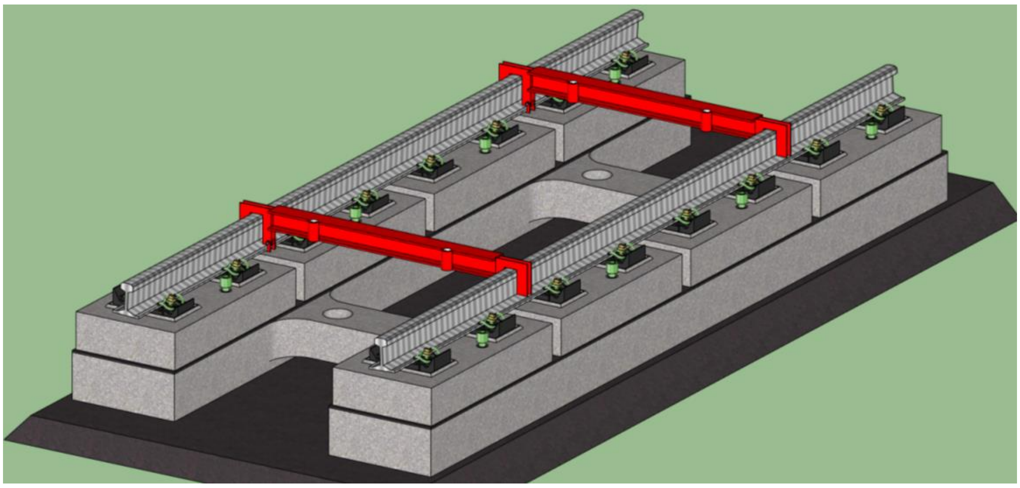
5. Steel pin installation (screwed onto the base slab)



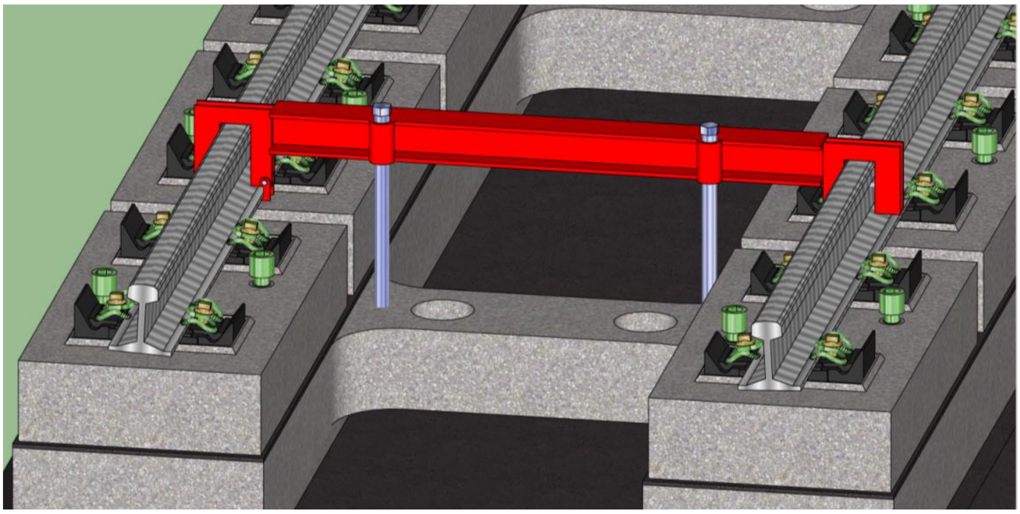
6. Rough rail positioning (premounted fastening system) by placing fastener plates within block cavities



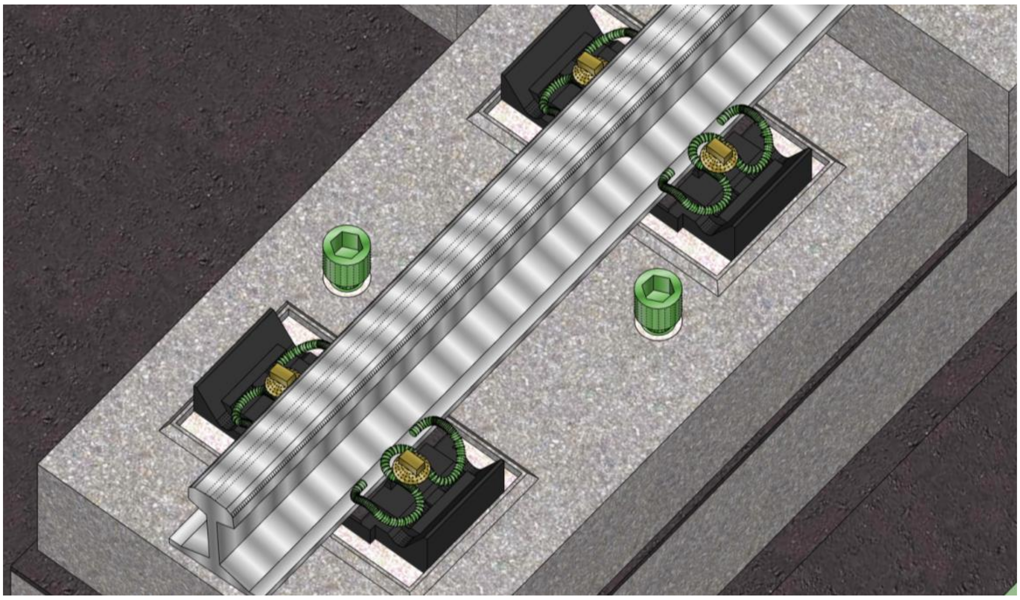
7. Installation of false sleepers to guarantee track gauge and rail tilt



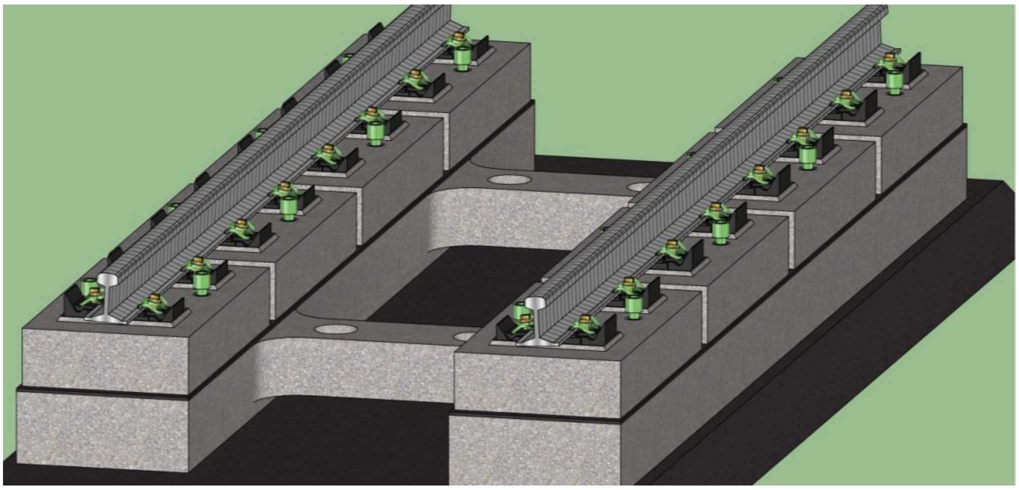
8. Fine rail positioning with false sleeper levelling mechanism



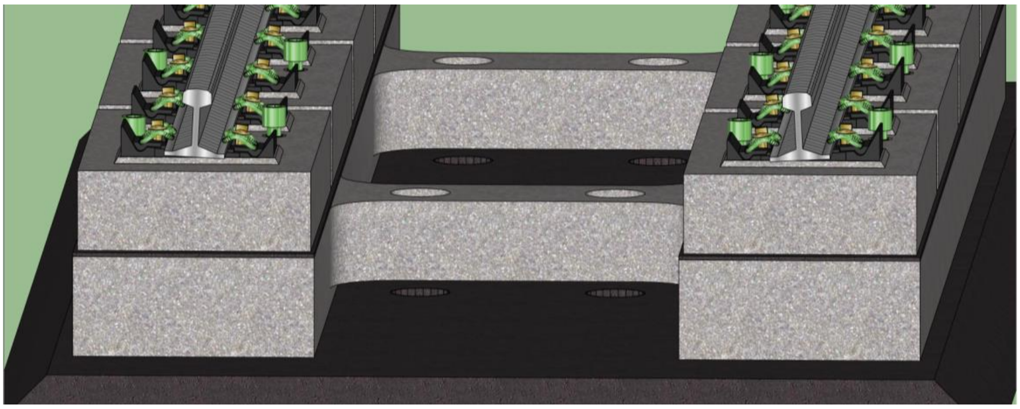
9. Pouring of mortar in block-pin and fastener-block in situ connection



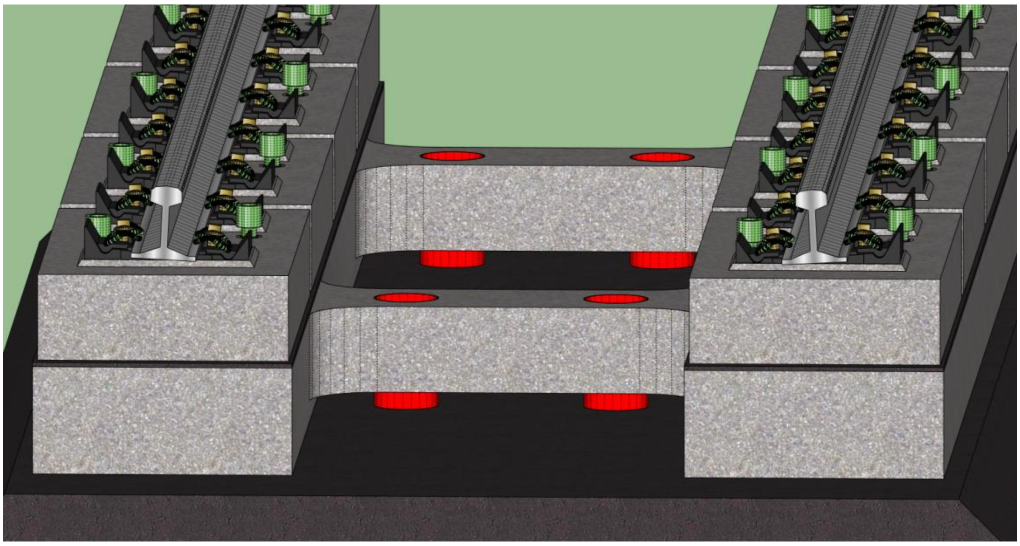
10. Recovery of false sleepers after mortar hardening



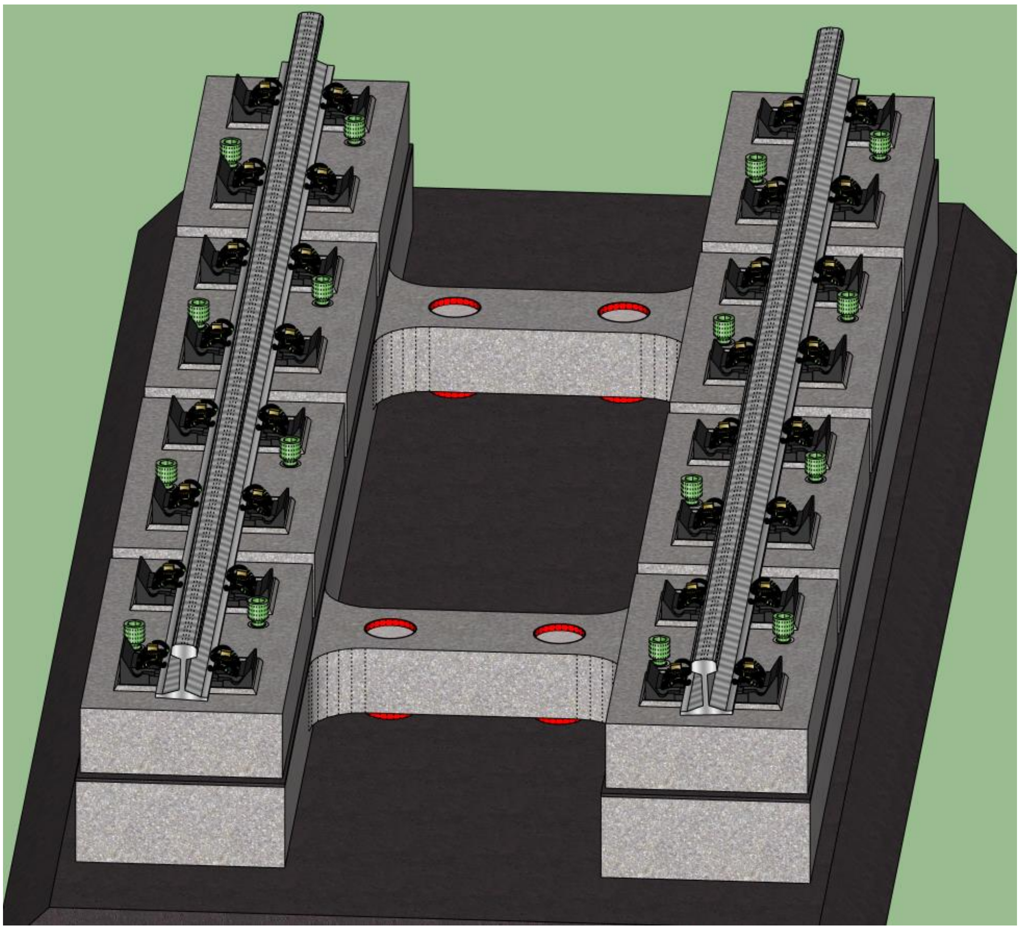
11. Drilling of holes in the subbase for slab connection to the subbase (where required)



12. Placement of cylindrical (pvc) formwork in the base slab through holes (where required)



13. Pouring of mortar to materialize the slab-subbase connection (where required)



3.2 LADDER TRACK

3.2.1 SYSTEM DESCRIPTION

The L-Track system is based on the concept of continuous rail support and industrialization of element fabrication.

Through the use of a specially designed fastening system, standard L-track modules may be used both for straight track and for curves with a radius greater than 300 m, thus benefiting from the scale economy of using standard precast elements for most track segments.

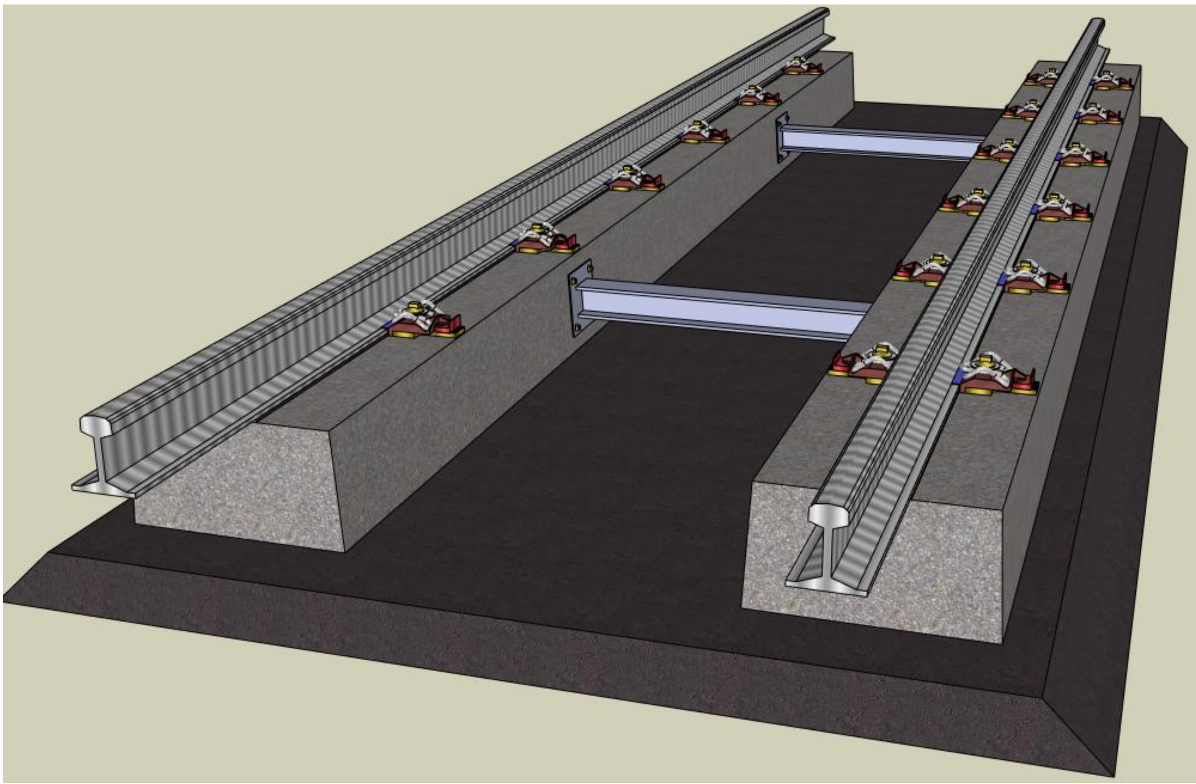


Fig 7: L-track system

The system is composed of 5,4 m long modules, each comprising the following components:

3.2.1.1 Longitudinal beams

Longitudinal beams are reinforced concrete elements 5,3 m long presenting a trapezoidal section with 300 mm height, 560 mm bottom width and 540 mm top width.

Both beams present embedded grooves and dowels on the top face, placed with a separation of 900mm between dowel axii and the first and last dowel axis at 400 mm from the beams ends. In curves with a radius under 3000 m, dowel separation is reduced to 600-700 mm to facilitate rail geometry and enhance lateral restraint.

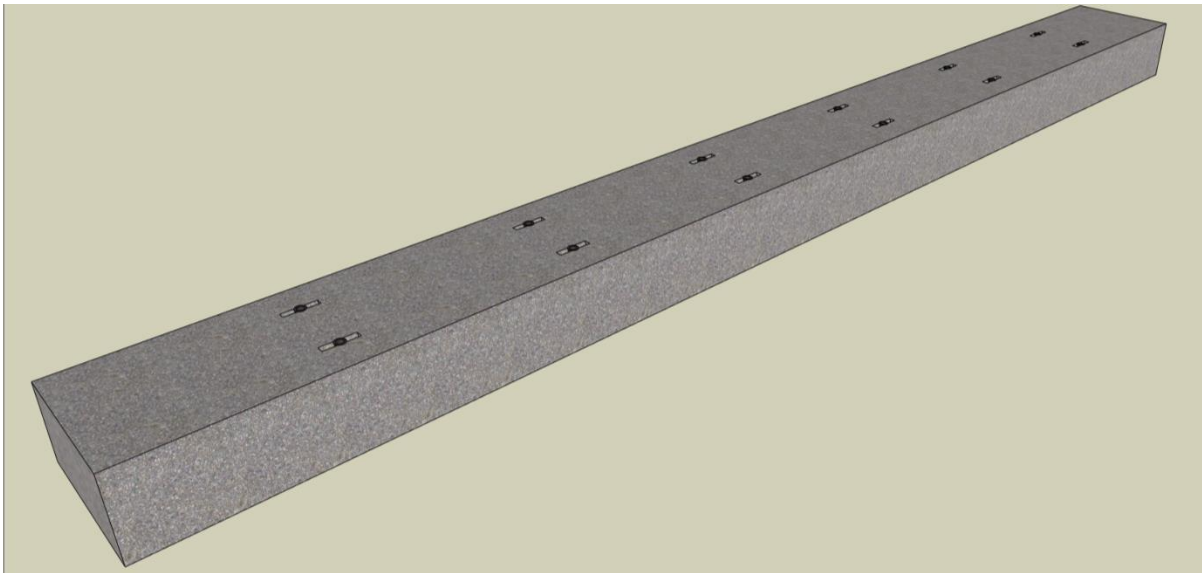


Fig 8: Longitudinal beam

3.2.1.2 Transversal beams

In order to guarantee the track gauge and prevent independent movement between longitudinal beams, two transversal beams are anchored *in situ* to the inner face of the longitudinal beams.

Said transversal beams present a standard HEB-100 cross-section, 967 mm of length, and end in square steel plates of 200 x 200 x 2 mm, tilted 4 degrees to match the concrete beam inner faces, with 4 symmetric 14 mm diameter cylindrical through holes placed at a 25 mm distance of the plate edges.

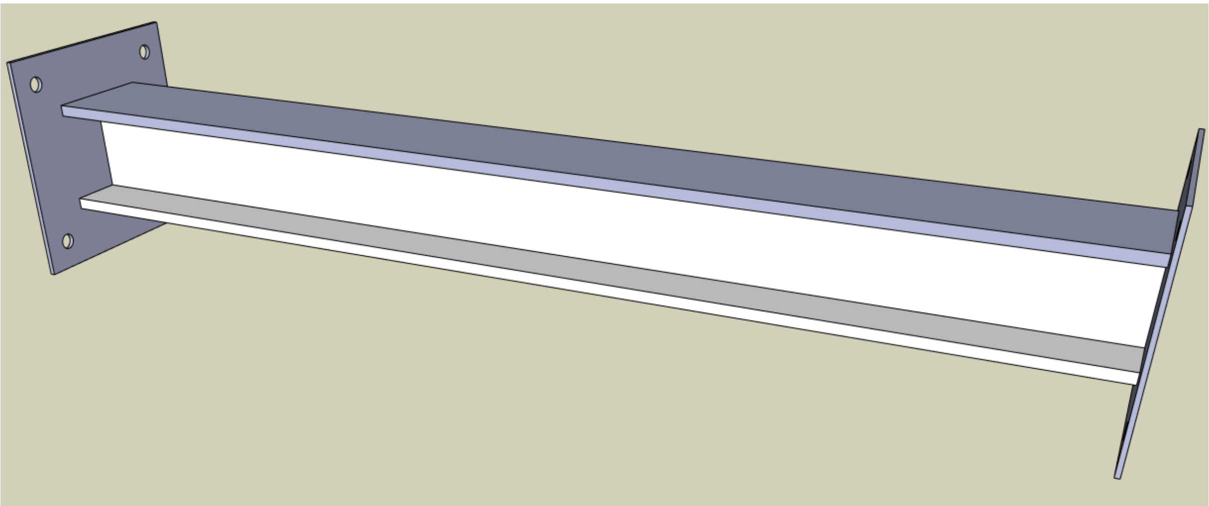


Fig 9: Transversal beam

3.2.1.3 Continuous rail pad

In order to provide adequately flexible support for the rail, continuous elastomeric under rail pads are used.

Said pads present a width of 170 mm, a thickness of 7 mm and cover the whole length of the longitudinal beams

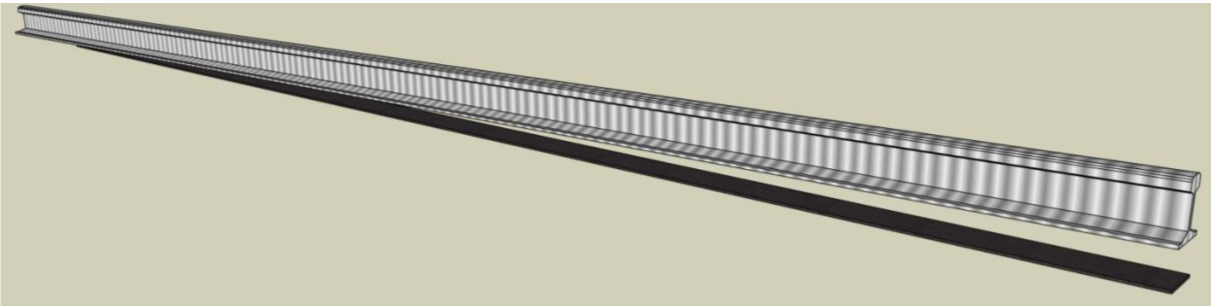


Fig 10: Continuous rail pad

3.2.1.4 Adaptable fastening system

The core component of the system, the newly developed adaptable fastening system from Vossloh is designed to provide +/- 6,5 mm initial horizontal adjustment plus an additional +/- 4 mm adjustment capability for maintenance.

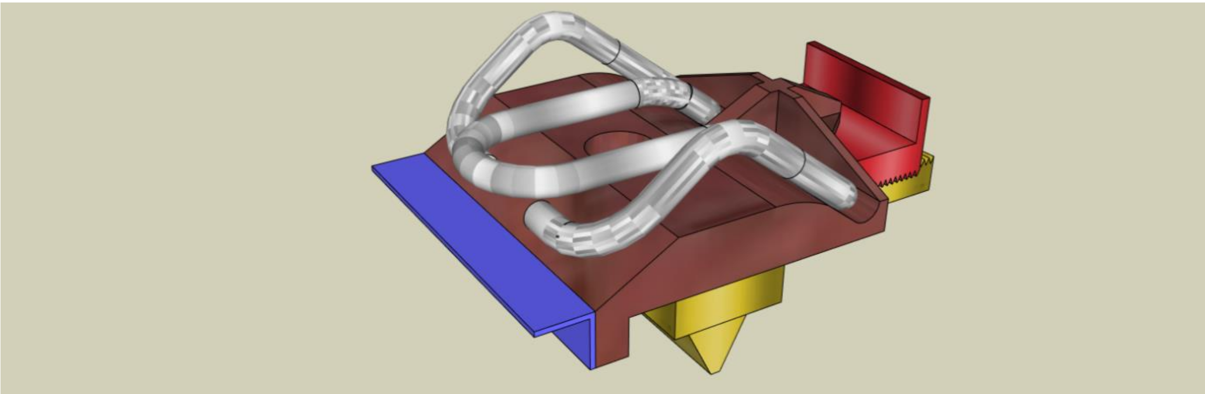


Fig 11: Adaptable fastening system

It is composed of the following elements:

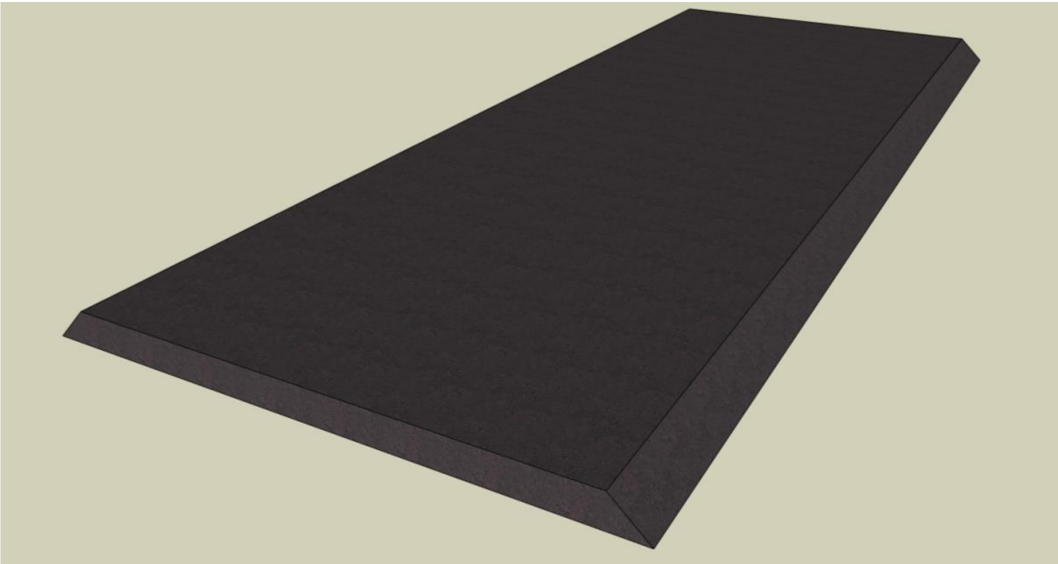
- Toothed base plate (bronze colored), provides general horizontal restraint by means of the metallic insert placed inside the concrete beam grooves
- Toothed adjustment plate (red colored), connected to the base plate through their intertwined teeth, restrains the spring plate horizontally. Provides the horizontal adjustment, as several positions relative to the base plate are available
- Spring plate (brown colored), provides restraint for the spring. Its horizontal position is fixed through the contact of its back ridge with the toothed adjustment plate
- Fastening spring (silver colored), provides vertical elastic restraint for the rail
- Load distribution plate (blue colored), distributes the fastening loads in the rail foot

3.2.2 System assembly

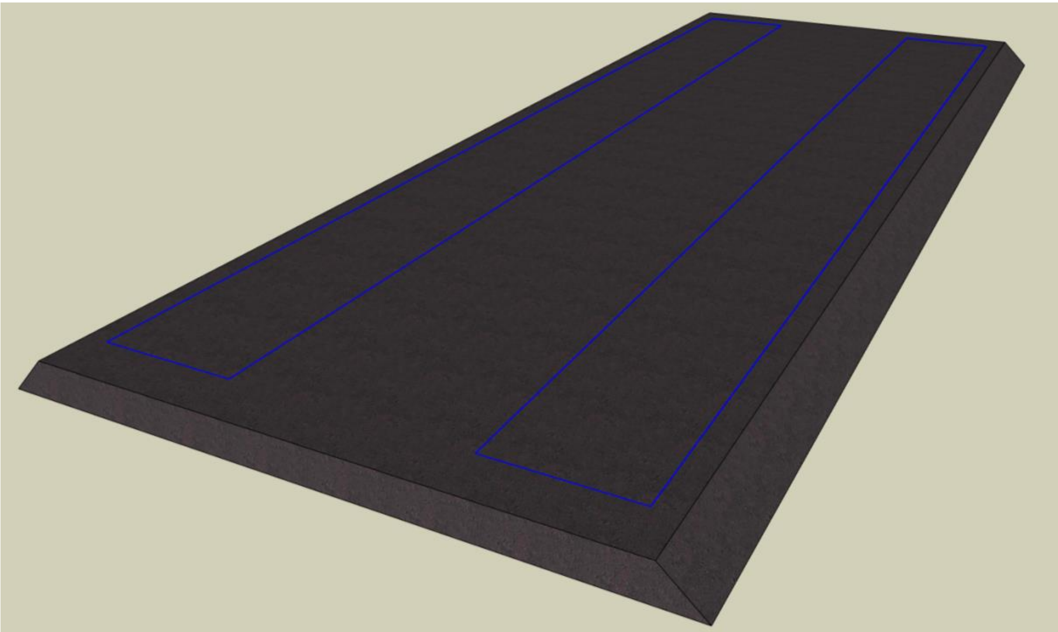
Even though both longitudinal and transversal beams are manufactured off-site and fasteners provide with considerable adjustment capabilities, the L-track system requires precise relative pre-positioning of the concrete elements in order to facilitate assembly.

The assembly process is composed of the following steps:

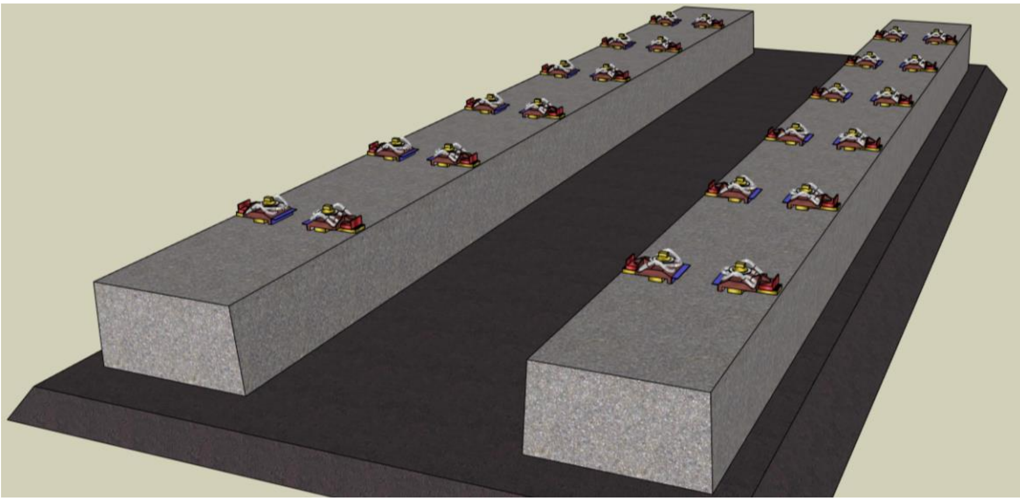
1. Bituminous sublayer application:



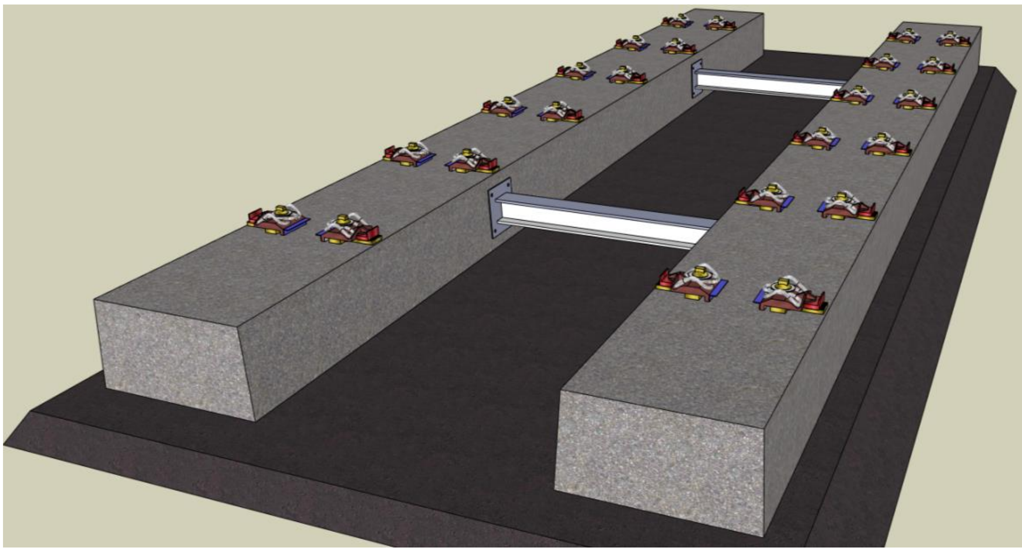
2. Rough topographic location of concrete beams. Beam **separation tolerance** < 2mm



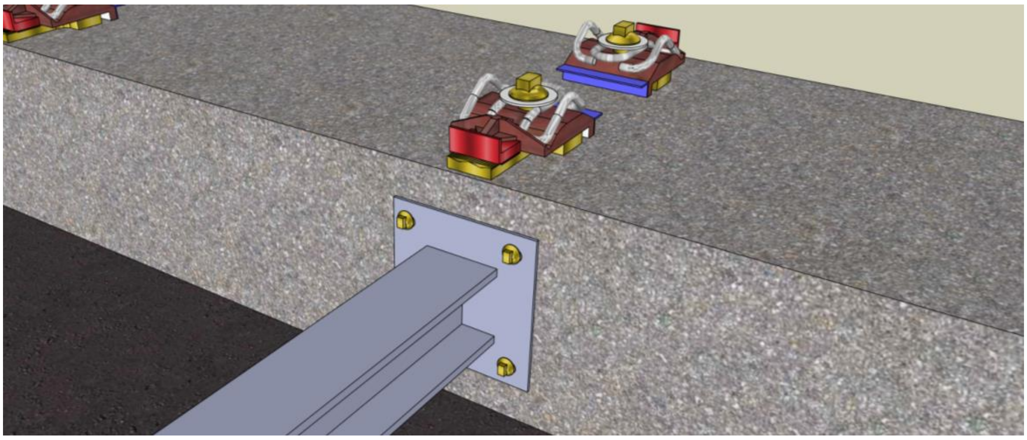
3. Longitudinal beam positioning (w/ premounted fasteners):



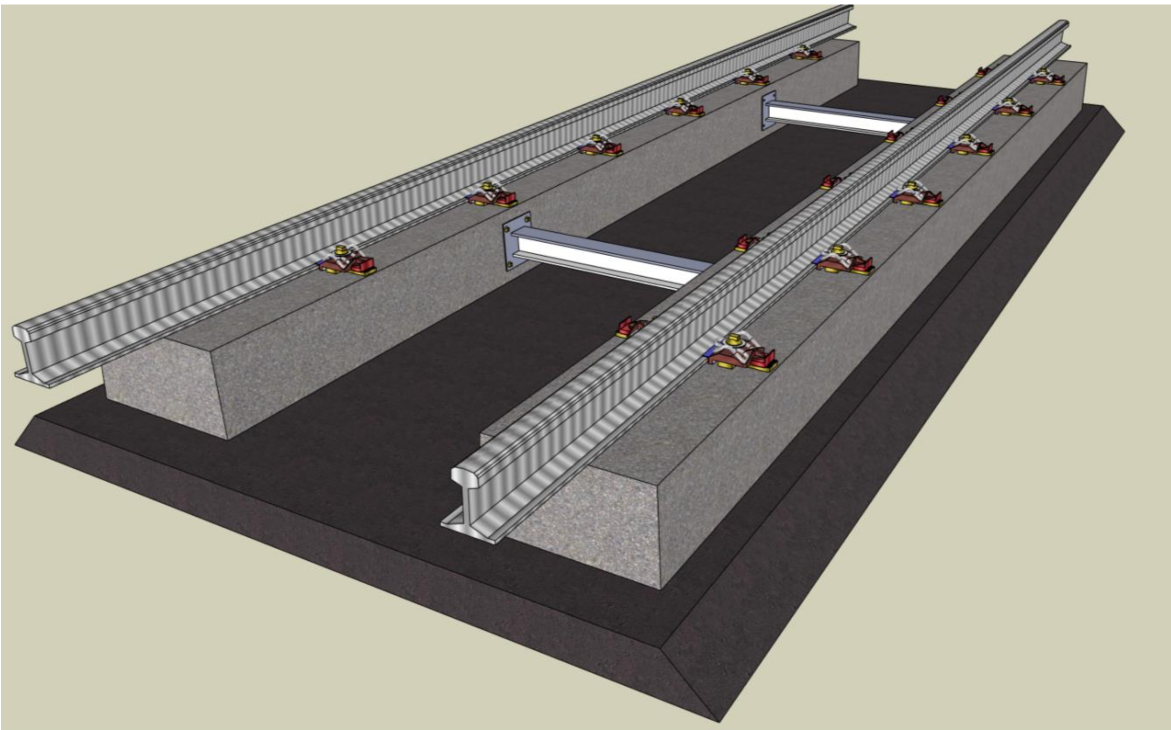
4. Pre-positioning of transversal beams:



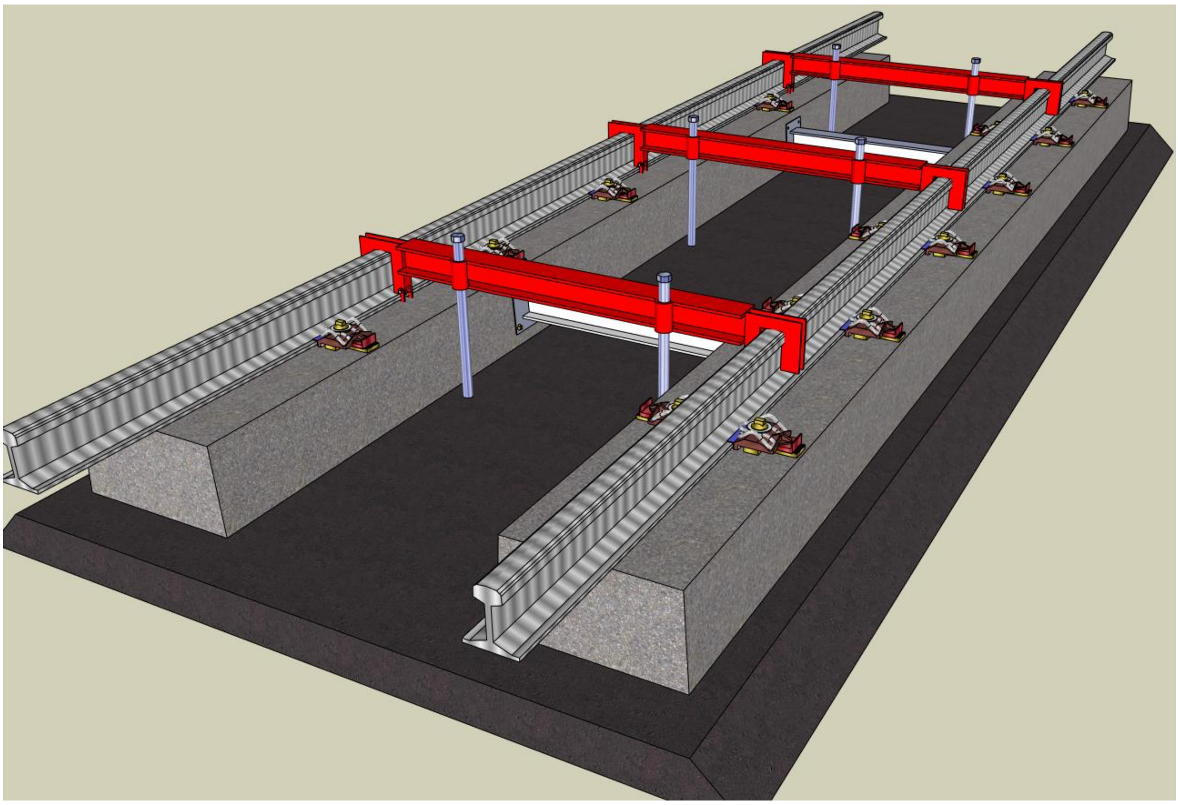
5. In situ transversal beam anchoring



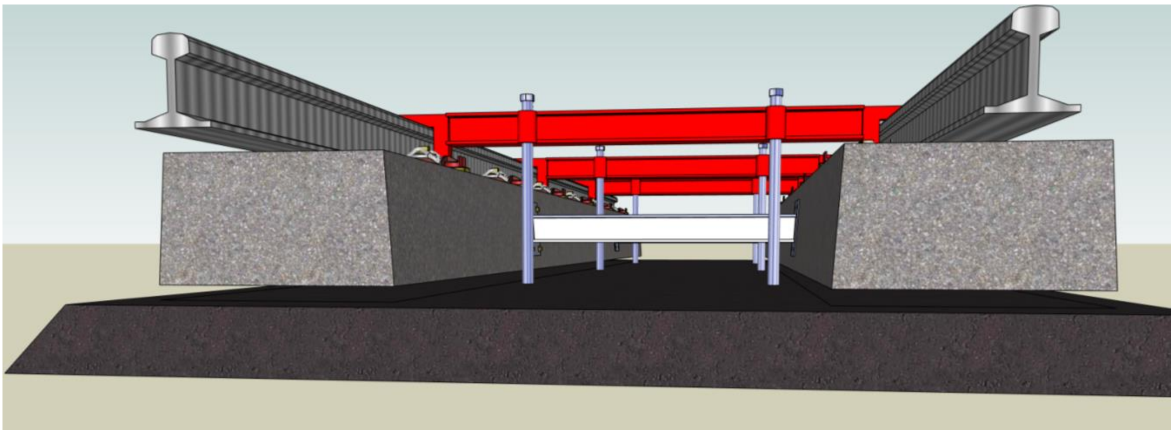
6. Rail pre-mounting:



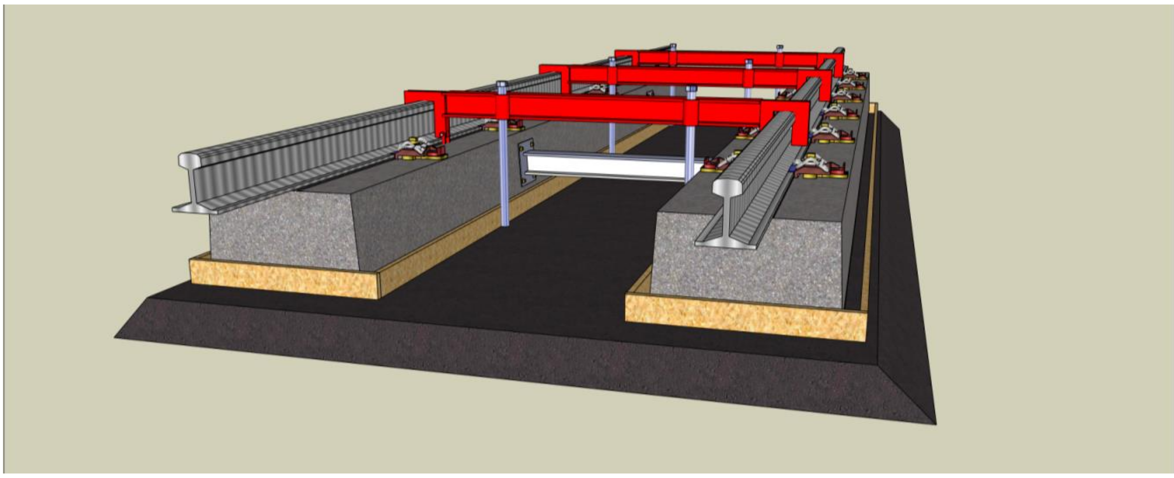
7. Installation of false sleepers:



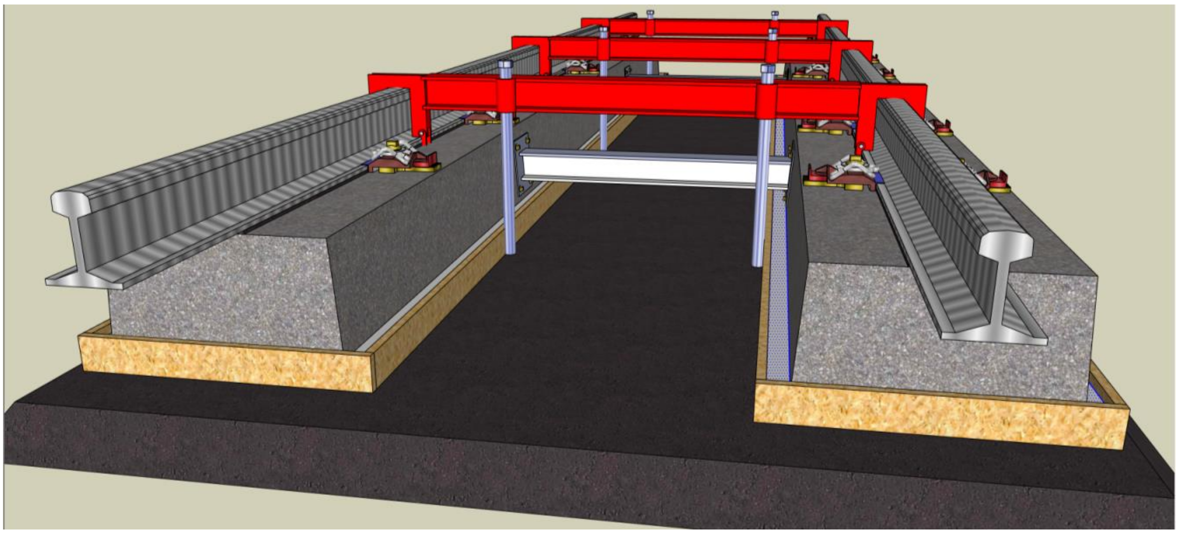
8. Fine vertical alignment adjustment by means of false sleeper mechanism



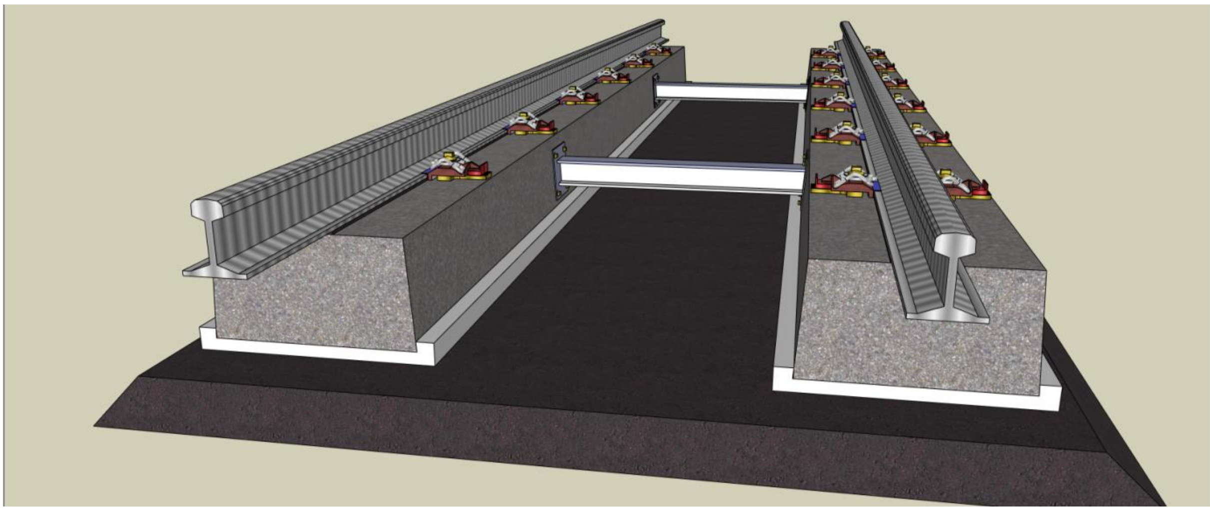
9. Installation of mortar bed formwork



10. Pouring of mortar bed



11. Dismantling of the mortar bed formwork, dismantling of false sleepers and final track geometry adjustments



4 Integrated monitoring system

4.1 MONITORING SYSTEM DESCRIPTION

4.1.1 INTRODUCTION

The whole and complete analysis of requirements and design of the integrated monitoring system is deployed in the D43.1.

Shown below is a brief description and summary of the most remarkable components of the monitoring system, along with the assembly procedure.

4.1.2 RFID

RFID sensor tag used to power and to collect data from this strain gauge is the V-Meter-DLCV10 manufactured by Farsens [10]. The VMETER-DCLV10 tag consists of a RFID chip (ANDY100D [11]) for energy harvesting and wireless communication, a start-up circuitry based on a voltage monitor, a micro-controller with integrated voltage reference and ADC (10 bits) and signal conditioning circuitry for measuring low voltage values.

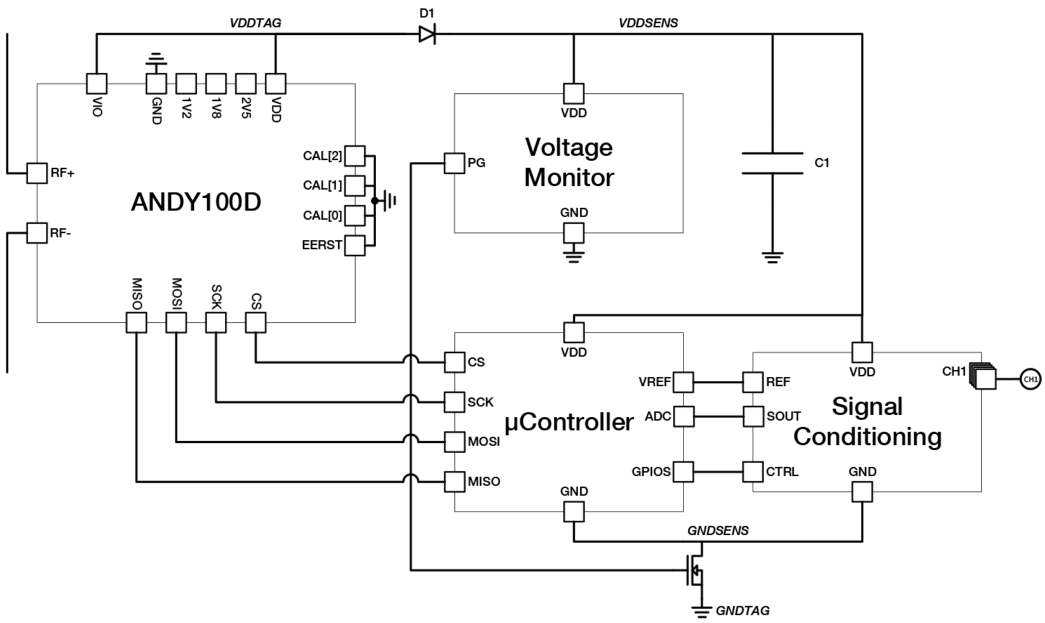


FIGURE 1 BASIC SCHEME OF THE VMETER-DLCV10 RFID SENSOR TAG [10]

The operation of measuring low voltage values is controlled with a micro-controller. Besides the CPU, the flash memory and the RAM memory the micro-controller includes a SPI (Serial Peripheral Interface, which is a communication protocol foe sensors, actuators, microcontrollers or other external devices used by ANDY 100 chip)) module , GPIOs, a 1.5V voltage reference and a 10 bit SAR ADC.

Finally, the signal conditioning is based on an instrumentation amplifier. The amplifier can be configured to have any gain between 1 and 1000 by setting the appropriate value of a resistor. The signal conditioning circuitry can be enabled/disabled with a NMOS switch in order to reduce power consumption when no measurements are being made.

Upon receiving a SPI directed read request from the UHF RFID reader, the ANDY100 generates SPI signaling towards the micro-controller. Given that the RFID communication protocol specifies timing restrictions for answer, the micro-controller returns the measurement value stored in a buffer and triggers a new measurement. Thus, the answer of the tag to the reader includes the value of the previous measurement.

In order to perform a new measurement, the micro-controller enables the signal conditioning and waits for the stabilization of the amplifier. After waiting the sensor stabilization time, an ADC measurement is taken using the 1.5V reference. Finally, the signal conditioning is disabled again to minimize power consumption. [10]

4.1.3 STRAIN GAUGE

For the monitoring purpose of the slab track, since it is a reinforced concrete structure, it has been selected a number of sensors that directly or indirectly are able to survey the stress state and deteriorarion phase of the element. In order to measure stresses, the most common sensors are strain gauges. Through the Hooke's Law strains, that are easier to measure, are translated into stresses. Stresses are spread on the structural element through the concrete, which is jointly fixed to the reinforcement steel bars. Therefore, strain gauges strategically located on reinforcement bars (rebars) are a typical configuration to monitor using RFID reinforced concrete elements.

Weldable strain gauges are commercialy available from many manufacturers. One of the main technical requirements for this element is a sufficient resistance, at least 1000Ω, in order to have the necessary voltage difference in the Wheatstone bridge, so that the RFID sensor tag is able to measure with accuracy enough. Although this high resistance is not so common, fortunately it could be found in the catalog of an European manufacturer.

The strain gauge selected belong to the so-called universal general-purpose strain gauges group. It consist of a constant grid completely encapsulated in polyimide, with large, rugged coppercoated tabs. It is primarily used for static and dynamic stress analysis. Table 1shows the datasheet of this strain gauge and Figure 2 below shows an augmented picture of the strain gauge.

TABLE 1 TECHNICAL SPECIFICATIONS OF THE STRAIN GAUGES

Manufacturer:	Vishay Precision Group (VPG)
Brand:	Micro Measurement
Strain type:	General Purpose Strain Gauge – Linear Pattern
Model:	CEA-06-250W-10C
Resistance:	1000Ω±0.3%
Strain range:	±5%
Temperature range:	-75ºC to + 175ºC
Dimensions:	6.35x11.43mm

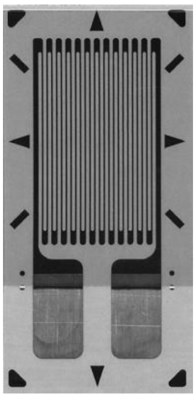


FIGURE 2. STRAIN GAUGE CEA-06-250W-10C

4.2 ASSEMBLING PROCEDURE

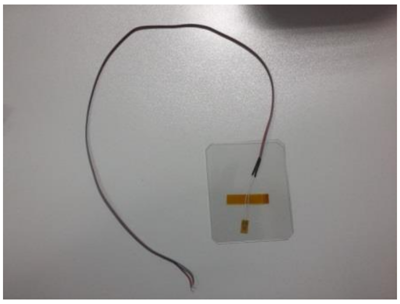
The assembly procedure consists of a number of steps, in which the different components are connected between themselves in order to obtain the definitive device which allows the detection of the strain in the reinforcement bars of the slab track.

The different required components are listed as follows:

- RFID V-meter (voltmeter)
- Resistances 1 kΩ
- PVC protection box
- Strain gauge
- Wire of connection

Wheatstone Bridge resistances of 1kΩ (left) & RFID Vmeter (right)

Selected box to encapsulate the entire solution



Strain Gauge (1kΩ±3.5%)

FIGURE 3. PREPARATION OF COMPONENTS

It can be seen that, apart from the basic components such as strain gauge and RFID V-meter, it is needed a PVC box in order to insert the RFID V-meter inside of it to protect, through the encapsulation, the device once the monitoring system will be embedded in the concrete, some resistances of 1 kΩ to implement the Wheatstone Bridge (see D.43.1) and some wires to connect between themselves all the components.

The electric scheme of connections is shown in the next figure (see Figure 5).

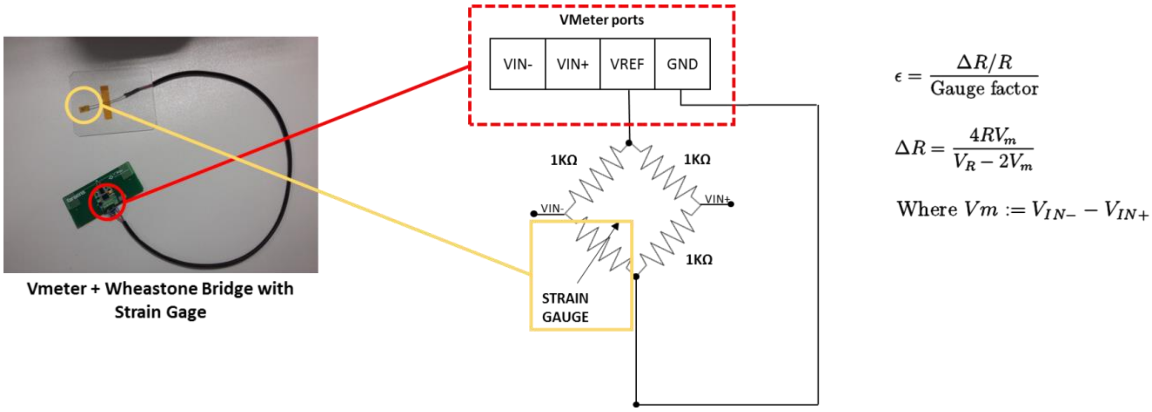


FIGURE 4. ELECTRICAL SCHEME OF CONNECTIONS

From the above points, the components were assembled in order to obtain the whole monitoring device which is compound by the strain gauge and RFID V-meter. The followed steps are described as follows:

- Connection between V-meter with Strain Gauge
- Encapsulation of V-meter inside of the PVC box
- Sealing the PVC box and the holes between box and wires in order to avoid the leakage of concrete inside of the box.
- Labelling of each of the different prototypes

Vmeter + Wheastone Bridge with Strain Gauge | **Encapsulation** | **Prototype and labelling**

FIGURE 5. ASEMBLING OF COMPONENTS

Once the process is finished, the device was ready to be installed in both prototypes of slab track developed during the WP1.1. of C4R project.

5 Installation procedure

5.1 PROCEDURE DESCRIPTION

Installation procedure consists of a number of steps which are based on the common procedure to install strain gauges with some remarkable differences among could be highlighted:

- Connections of the strain gauge to the RFID V-meter which are inserted into a PVC Box
- Wires of connection embedded in the concrete which do not leave from it.
- Need of installing the PVC box enough close to the strain gauge and at the same time, in a way that the RFID keep certain distance between V-meter and rebar in order to avoid interferences.
- System to hold and anchor the PVC box between the bars until the concrete is poured.

Having taken into consideration these differences and drawbacks in the installation procedure, a new one was defined which is described as follows:

1. Polishing the surface of the bar where the strain gauge will be installed. The surface should look like a mirror. The means to carry out this task will compound by a grinder, a sander and sandpaper for the hand polishing.

FIGURE 6. POLISHING THE SURFACE OF THE BARS OF THE SLAB TRACK PROTOTYPE

2. Pouring a little bit of acid solution (red) and polishing again in order to remove imperfections.
3. Applying acid solution (red) and basic solution (blue).
4. Cleaning of the polishing surface.
5. The cleaning will be carried out through the use of sterile gauzes. A number of gauzes will be used, adding successively acid and basic solution, until checking that there is not any signal of dirty.

FIGURE 7. CLEANING THE SURFACE OF THE BARS THROUGH THE USE OF AN ACID AND BASIC SOLUTIONS

6. Selecting the final position of the strain gauge on the rebar.
7. Applying of scotch tape on the strain gauge.
8. Placing the strain gauge on the rebar.
9. Applying of glue. Pressing 5 minutes in order to dry the adhesive with the filter paper to get a correct spread of the glue.
10. Remove carefully the scotch tape avoiding moving the strain gauge.

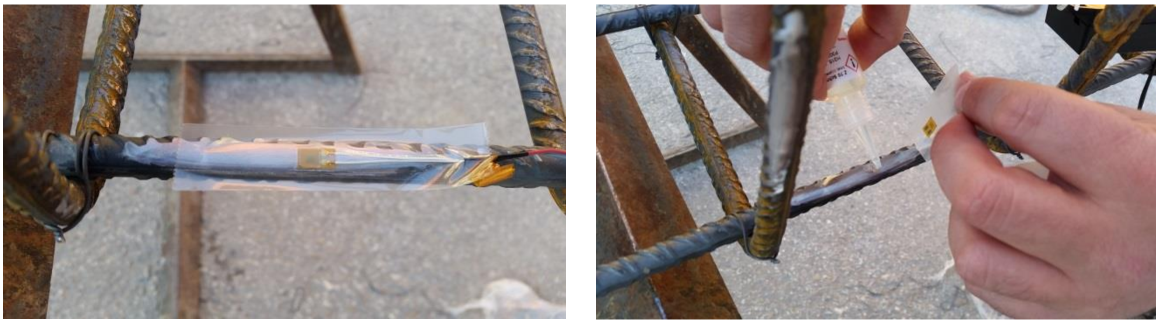


FIGURE 8. GLUING OF THE STRAIN GAUGE IN THE BARS

11. Protecting the strain gauge with plastic bands, paying attention on the connection with the wires.
12. Assuring the system through the use of adhesive bands and flanges in a manner that RFID device stays placed between the outers longitudinal bars.

FIGURE 9. PROTECTING STRAIN GAUGE AND INSTALLATION OF RFID V-METER (INSIDE OF PVC BOX)

5.2 LOCATION OF MONITORING SYSTEM IN 3MB AND L-TRACK PROTOTYPES

The first idea was to check the performance of the monitoring system based on RFID technology, embedded in the 3 MB slab track prototype. This point was justified because of the fact that the 3 MB slab model prototype was in a more advanced phase of construction than the L-Track.

In this manner, having taken into consideration the geometry, the reinforcement bars and the special features of this prototype, a number of points to check and measure were determined (see Figure 11). The reasons to decide these points were justified by the preliminary structural studies of the 3MB slab track and by the reinforcement bars design (Figure 10), since in these points the strains and stresses achieve their maximum values.

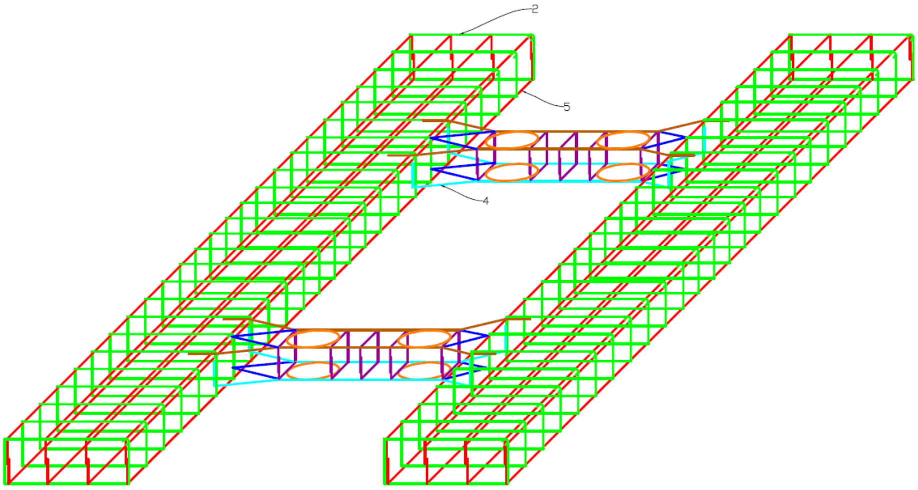


FIGURE 10. REINFORCEMENT BARS DESIGN OF 3MB PROTOTYPE

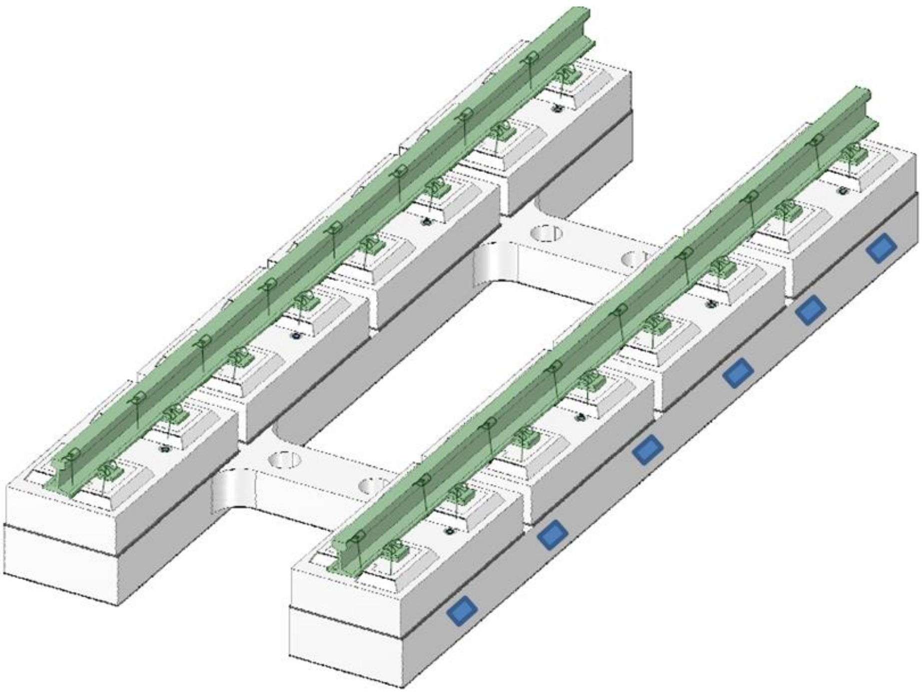


FIGURE 11. LOCATION OF THE MONITORING SYSTEM IN THE 3MB PROTOTYPE

Once, the points to check were defined, the next step was to decide in which bar will be installed the strain gauges. Main drawbacks at the time of perform the installation was related to the next facts:

- Maximum concrete thickness which the RFID electromagnetic wave is able to pass through (see D 43.1).
- Geometric design of the reinforcement bars, which restrict the possibilities of installation.
- Concrete cover is around of 5 cm in the different regulations and technical guides.

After considering the different possibilities, it is decided to install six different strain gauges together with the RFID in one of the two 'arms' of the slab track prototype as it can be seen in the Figure 12.

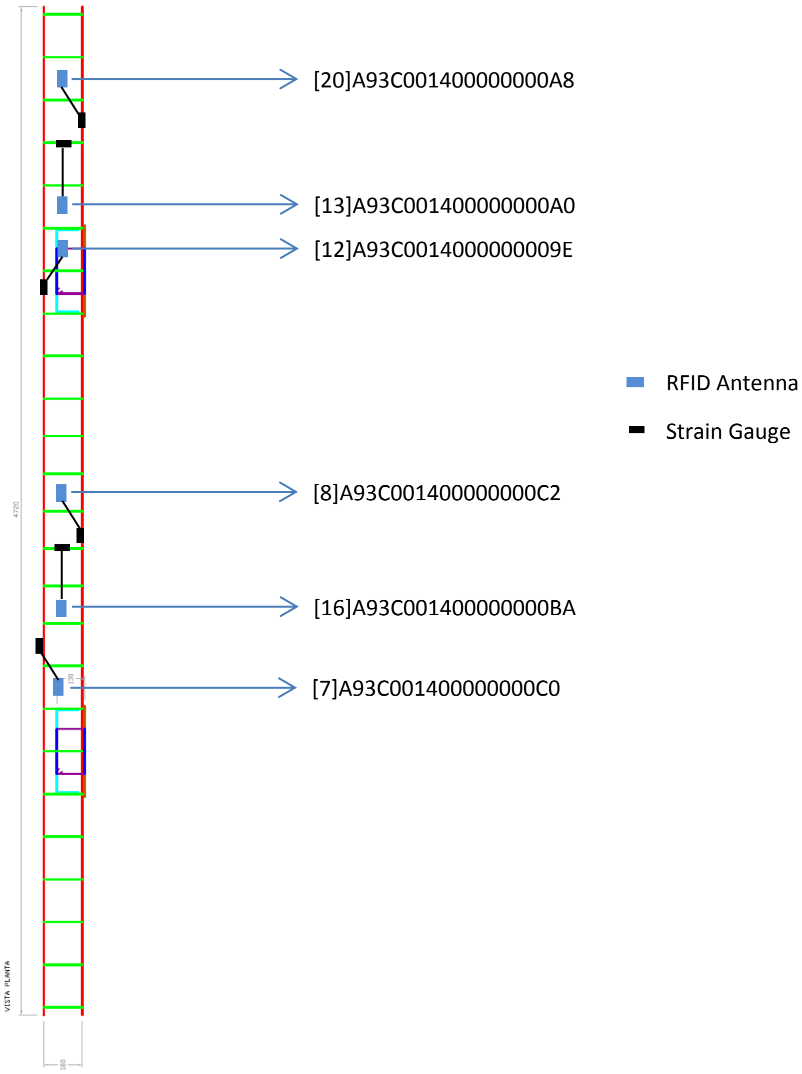


Figure 12. Location of the different strain gauges in the 3 MB slab track reinforcement bars

In addition, in order to ease the task of checking and testing the performance of the devices, every one of them was labelled with a QR code and an alphanumeric tag (Figure 12). In this manner, during the testing procedure, once the prototype was built, installed in the CEDEX Track Box and subjected to the different fatigue test, the different devices could be easily detected in their accurate position.

On the other hand, once the different monitoring system devices were installed in the 3 MB slab track prototype, and the procedure of installation was clearly stablished, it was decided to install a number of them in the L-Track.

The followed procedure was the same stablished that in the previous prototype. In this case, the points to check was determined under the same premises of the 3 MB slab track prototype, placing the monitoring devices in the location where the strains and stresses present their maximum values (Figure 13).

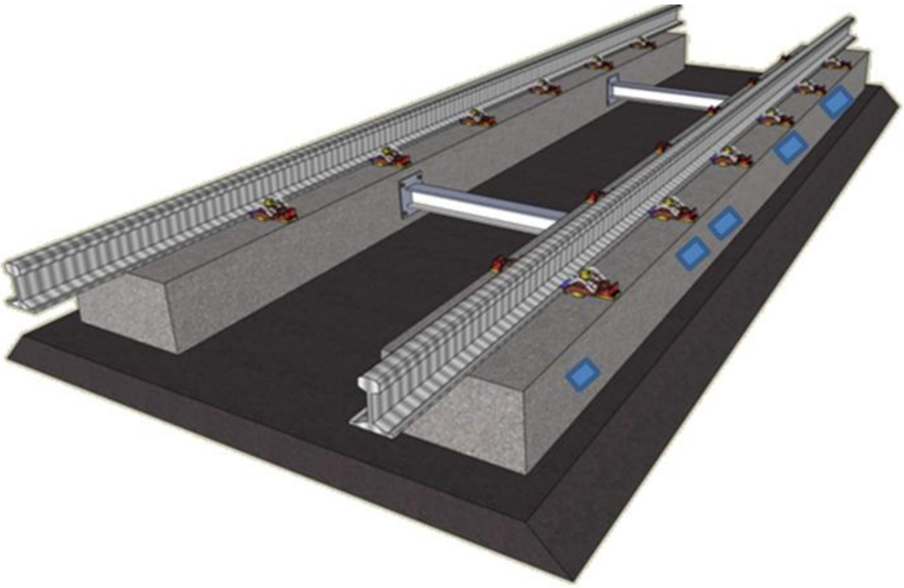


FIGURE 13. LOCATION OF THE MONITORING SYSTEM IN THE L-TRACK PROTOTYPE

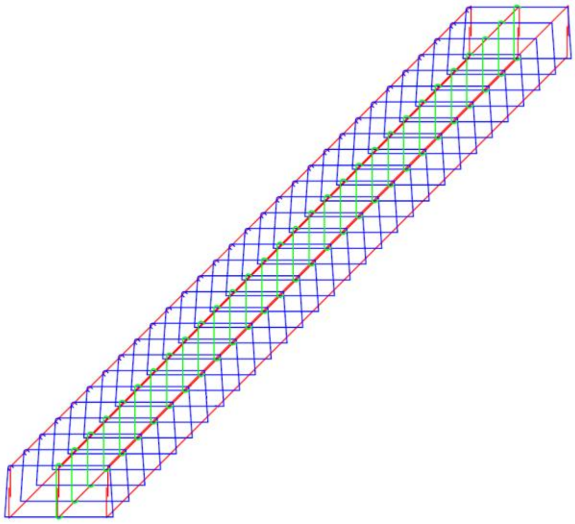


FIGURE 14. REINFORCEMENT BARS DESIGN OF L-TRACK PROTOTYPE

The specific location in the reinforcement bars design for both RFID antenna and strain gauges can be seen in the follow figure (Figure 15).

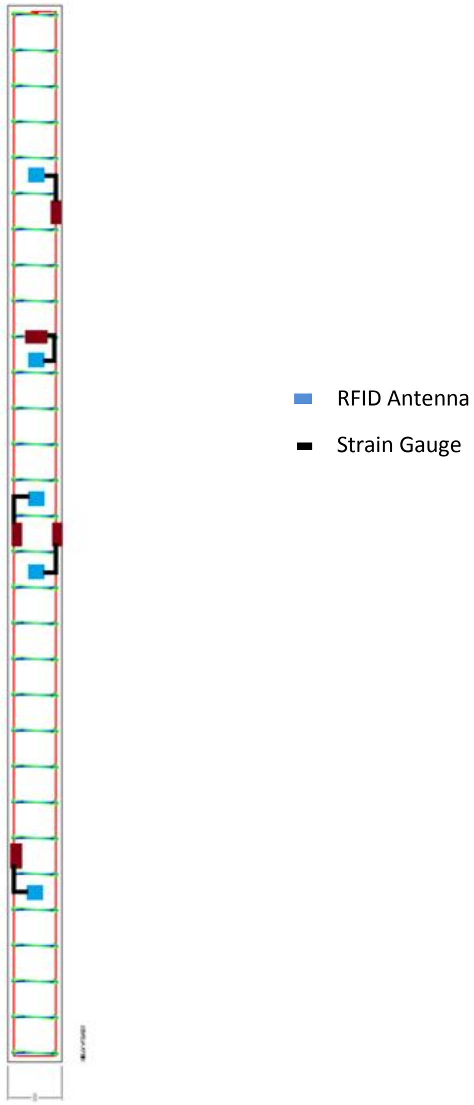


FIGURE 15. L-TRACK SLAB TRACK

6 Testing procedure and test results

6.1 CEDEX-Track Box

CEDEX Track Box (CFC) is a 21 m long, 5 m wide and 4 m deep facility whose main objective is to test, at 1:1 scale, complete railway track sections of conventional and high speed lines for passenger and freight trains, at speeds up to 400 km/h.

The testing facility was designed, built and developed as part of SUPERTRACK ("Sustained Performance of Railway Tracks", 2001-05) and INNOTRACK ('Innovative Track Systems', 2005-2009) projects funded by the European Union 5st and 6st Framework Programs, respectively. Figure 16 shows a general view of the testing facility.

Figure 16. General view of CEDEX Track Box

Its principal benefit is the possibility of performing fatigue tests in a fast way as in one working week, the effect of the passing-by of trains during a year in a real section can be modelled.

The reproduction of the effect of the approaching, passing-by and departing of a train in a test cross-section, as it occurs in a real track section, is performed by application of loads, adequately unphased as a function of the velocity of the train which is being simulated, produced by three pairs of servo-hydraulic actuators (that can apply a maximum load of 250 kN at a frequency of 50 Hz), placed on each rail and 1,5 m longitudinally separated, as seen in Figure 2.

Furthermore, the reproduction of wheel and track imperfection effects that produces low amplitude high frequency dynamic loads can also be carried out by the use of two piezoelectric actuators that can apply loads up to 20 kN at 300 Hz.

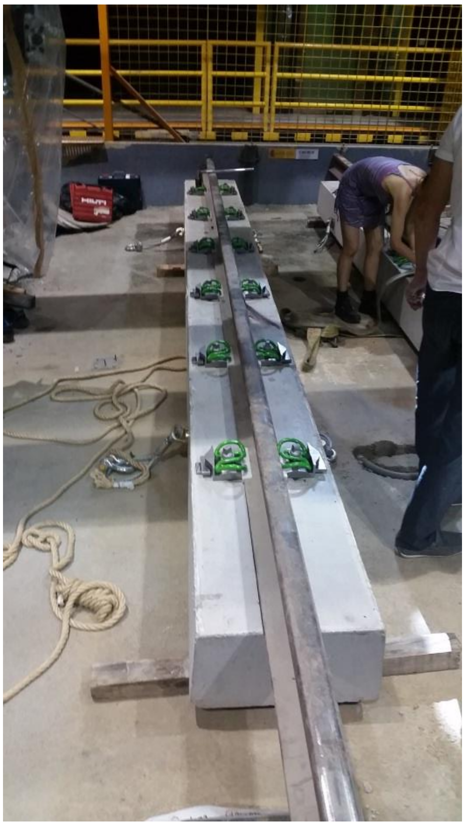
The railway track response, in terms of displacements, velocities, accelerations and pressures, is collected from a great number of linear variable differential transformers (LVDTs), geophones, accelerometers and pressure cells installed inside both the embankment and the bed layers (ballast, sub-ballast and form layer) of the track.

On the other hand, the railway superstructure response is recorded with mechanical displacement transducers, laser sensors, geophones and accelerometers installed on the different track components (rail, sleeper and railpad). The acquisition data unit can receive information from 150 sensors at the same time.

6.2 GOAL

The performance of the different devices installed in the 3MB and L-Track prototypes were checked during the fatigue test performed in the CEDEX Track Box under real cycles of load. Some pictures of the 3MB and L-track prototypes could be seen in the next figure (Figure 17).

(a)



(b)

FIGURE 17. 3MB (A) AND L-TRACK (B) PROTOTYPES PLACED AT THE CEDEX TRACK BOX FACILITIES

The goal of the test was to check the performance of the monitoring system installed in a real environment. Although the in-lab test were successfully (D43.1), it was needed to check the potential of the V-meter and antenna in the real slab track prototypes where there are a number of parameters and elements not considered in the in-lab tests such as rails, pads, fasteners and so on, which could generate interferences or induct attenuations in the process of taking readings.

The used device to read the different V-meter RFID tags was a Nordic ID Merlin Cross Dipole One-series EU HT00101. This device provides fast and accurate RFID reading in long-range. The cross dipole antenna enables to read tag regardless the tag position. The technical specifications are shown in the following table:

TABLE 2 TECHNICAL SPECIFICATIONS

Supported standard	ISO 18000-63 (EPC Class 1 Gen2 V2)
RF Power:	ERP +33 dBm (2W)
Frequency	865.6-867.6 MHz
Nominal reading distance	7 m

FIGURE 18. HANDHELD RFID READER (NORDIC ID MERLIN UHF RFID CROSS DIPOLE ONE)

6.3 RESULTS

The procedure to check the performance of the monitoring system consisted of getting readings closing the RFID reader to the theoretical location of the different RFID tags. Thanks to the location schemes (see Figure 12 and Figure 15) the task was easy and quick.

All the different monitoring devices offered quick and clear reading in few seconds when the RFID reader was brought near to the theoretical position of the device. It should be noted that it did not need to put in contact with the RFID reader with the concrete block of the slab track prototypes but the reading distance complied the ranges obtained during the in-lab test performed previously (see D43.1).

In addition, as it said before, the different RFID tags were labelled with a QR code and an alphanumeric tag. This fact allowed the detection and identification of every one of the different monitoring devices, ensuring the correct performance and the location where were installed.

Then, it is shown a number of pictures at which it could be seen the relation between the monitoring device during the installation phase and the reading taken from it during the performance test at CEDEX, making sure the good performance of the system in real condition under cycles of load.

FIGURE 19. [20]A93C001400000000A8

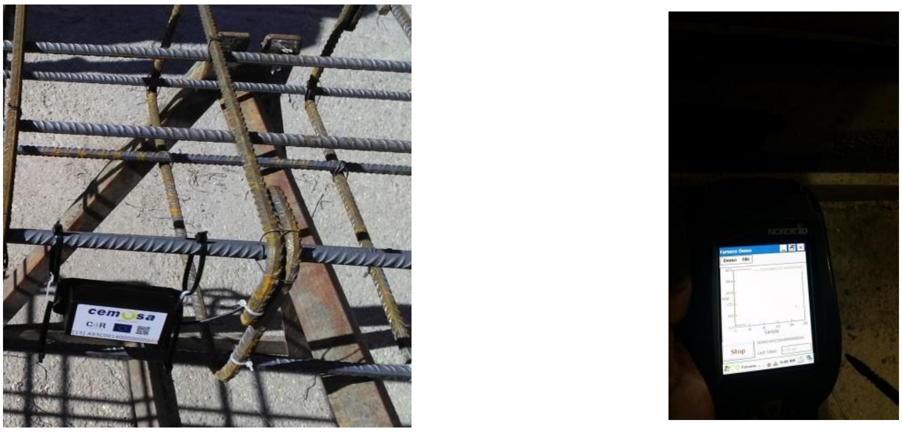


FIGURE 20. [20]A93C001400000000A0

FIGURE 21. [20]A93C00140000000009E

FIGURE 22. [20]A93C001400000000C2

FIGURE 23. [20]A93C001400000000BA

FIGURE 24. [20]A93C001400000000C0

7 Conclusions and next steps

The results from the tests performed on the devised monitoring system open the door to several intriguing and potent possibilities for the monitoring of slab tracks via RFID tags.

For instance, on-board RFID readers could be used to recover live data on the structural health and dynamic response of the different elements in the track, with little to no added cost, and saving significant amount of work, possession time and labour costs currently being spent in inspection and monitoring.

Likewise, more advanced RFID systems (e.g. active tags) could be used to implement continuous monitoring and complex data gathering systems, powered wirelessly by the RFID antennas, with the data recovery and transport issues being solved without the need of additional systems.

In that context, the following steps in the development of structural health monitoring for the new slab track systems would be:

- To devise an optimized COTS-sensor deployment for both systems, so that the recovered data can be turned to useful information with minimal post-processing
- To map the dynamic behaviour of the track systems under several partial component failure conditions, so that imminent non critical failure or malfunction of a component may be detected and predicted by a monitoring system based on accelerometers
- To extend the principles of the developed monitoring philosophy to other track systems and elements, where applicable

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