

LIAISON

Making transport infrastructure
climate-neutral, sustainable and circular

INFOPACK - MAY 2026

SECTOR 2 OF 5

SUSTAINABLE ELEMENTS

Structural elements for sustainable TI

Smart precast geopolymer solution

FASTER REPAIRS, LOWER-CARBON MATERIALS, AND LONGER-LASTING ROAD PERFORMANCE

SECTOR 2 of 5
SUSTAINABLE ELEMENTS



Keeping road networks safe and reliable often comes down to one persistent challenge: how to repair damaged pavement quickly, without long closures, repeat interventions, or heavy environmental impacts. Traditional rigid pavement repairs can be slow, disruptive, and material-intensive. At the same time, conventional cement-based solutions carry a significant carbon footprint.

KER 5 addresses these issues with a smart precast rigid pavement solution made using geopolymer-based materials and designed for rapid slab replacement. The approach combines the speed and precision of precast concrete slabs with the sustainability potential of cement-free geopolymer binders, using industrial by-products such as Ground Granulated Blast Furnace Slag (GGBS) and Fly Ash (FA) as key ingredients.

What makes this solution especially practical is its focus on the real-world mechanics of repair. Precast slabs allow a damaged section of pavement to be removed and replaced individually, rather than reconstructing larger areas. This can reduce traffic disruption and deliver a more predictable, high-quality surface. To make installation and alignment easier on site, the concept includes a lifting and levelling

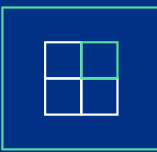
insert that helps teams position slabs accurately and adjust final levels to achieve a consistent riding surface.

Another important innovation is the slab-to-slab connection design. In many existing replacement approaches, large mortar-filled areas around dowels can become weak points, leading to cracking, water infiltration, and higher maintenance needs. KER 5 proposes a more robust detail by minimising dowel cavity size and applying a controlled grout injection method (inspired by bridge post-tensioning duct grouting). This supports better confinement around the dowel using the slab's reinforcement mesh, improving long-term performance.

To ensure that the material is fit for purpose, geopolymer concrete mixtures are being developed to meet the structural requirements of rigid pavements, without the need for thermal curing, through a structured programme of testing different formulations, including durability assessments (such as water penetration and chloride exposure tests).

Overall, KER 5 demonstrates how low-carbon materials and smarter precast design can work together to deliver faster, cleaner, and more durable rigid pavement maintenance—with clear potential for scaling across road networks where uptime, safety, and sustainability all matter.

BENEFITS

-  MODULAR DESIGN FOR QUICK AND EASY INSTALLATION WITH MINIMAL LABOUR
-  FASTER PAVEMENT REPAIRS VIA INDIVIDUAL PRECAST SLAB REPLACEMENT
-  LOWER-CARBON MATERIALS USING GEOPOLYMER BINDERS (SLAG/FLY ASH)
-  LONG-TERM DURABILITY THROUGH IMPROVED DOWEL/GROUT CONNECTION DETAILS
-  MORE PRECISE INSTALLATION WITH LIFTING AND LEVELLING INSERTS
-  REDUCED TRAFFIC DISRUPTION AND MORE PREDICTABLE MAINTENANCE OUTCOMES

ROADMAP TO IMPLEMENTATION



Road construction and maintenance are among the most material- and carbon-intensive activities in transport infrastructure. Conventional asphalt relies heavily on oil-based bitumen, contributing significantly to greenhouse gas emissions. To meet Europe’s climate and circular economy goals, road materials must evolve toward lower-carbon, resource-efficient alternatives.

KER 3 addresses this challenge by developing and validating innovative bio-asphalts, in which conventional bitumen is partially or fully replaced with bio-based binders derived from renewable and residual resources. Developed within the LIAISON project by the University of Cantabria, the solution explores how bio-asphalts can deliver comparable — or even superior — performance while significantly reducing environmental impact.

Two bio-binder solutions are being assessed. The first replaces up to 30% of conventional bitumen with lignin, a by-product of the paper industry. The second fully replaces oil-based bitumen using a combination of natural bitumen and a bio-based oil rejuvenator derived from cashew nutshells, a residue from the food industry. Both approaches reduce reliance on virgin fossil materials while promoting circular use of industrial by-products. Extensive laboratory testing has been carried out

to evaluate the physical, rheological, thermal, and mechanical performance of the bio-binders and resulting asphalt mixtures. Bio-asphalts were tested under standard European procedures and compared directly with conventional asphalt mixtures. Bio-asphalts were tested under standard European procedures and compared directly with conventional asphalt mixtures. Results show that both bio-asphalts comply with Spanish technical specifications, with the fully bio-based solution even outperforming traditional asphalt in key mechanical indicators.

Recyclability is a core aspect of the innovation. Artificial aging tests assess whether bio-asphalts can be reused at similar rates to conventional mixtures, ensuring compatibility with existing asphalt recycling practices. Long-term performance is further evaluated using a Circular Road Simulator, replicating traffic loading conditions in a controlled environment.

The solution will be validated at full scale on a pilot road section in Cantabria, where production, laying, and compaction are monitored to identify upscaling barriers. Environmental, social, and economic impacts will be assessed through Life Cycle Assessment and Life Cycle Costing, aligned with the LIAISON Dynamic Multi-Infrastructure Governance Framework (DMIGF). KER 3 demonstrates how bio-based materials can enable durable, recyclable, and climate-positive road pavements, supporting the transition to low-carbon transport infrastructure.

BENEFITS

-  LOWER CARBON FOOTPRINT BY REDUCING OR ELIMINATING OIL-BASED BITUMEN
-  USE OF BIO-BASED AND RESIDUAL MATERIALS (LIGNIN, CASHEW NUTSHELL DERIVATIVES)
-  COMPARABLE OR IMPROVED MECHANICAL PERFORMANCE VS CONVENTIONAL ASPHALT
-  COMPATIBILITY WITH ASPHALT RECYCLING PRACTICES
-  VALIDATED THROUGH LABORATORY, SIMULATOR, AND REAL-ROAD TESTING
-  SUPPORTS EU CIRCULAR ECONOMY AND CLIMATE GOALS

ROADMAP TO IMPLEMENTATION



Concrete beams are fundamental components of bridges, footbridges, and many transport structures. Yet conventional cast-in-situ construction methods remain labour-intensive, waste-generating, and imprecise, often leading to over-design and unnecessary material use. In a sector facing skills shortages and growing pressure to decarbonise, new approaches are urgently needed.

The Sustainable Smart Beams solution introduces a digitally driven solution for the design and fabrication of sustainable “smart” reinforced concrete beams, developed within the LIAISON project by École Nationale des Ponts et Chaussées (ENPC) together with industrial partners. The innovation combines structural optimisation, robotic fabrication, advanced formwork technologies, and embedded monitoring, enabling beams that are lighter, more accurate, and digitally traceable throughout their life cycle.

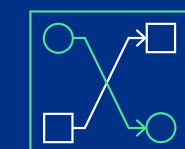
At the heart of the solution is a performance-based, generative design process compliant with Eurocode 2. Instead of conventional prismatic beams, the smart beams integrate internal cavities and optimised geometries, reducing concrete use by up to 40% while maintaining structural safety. This reduction directly lowers embodied carbon

and material consumption. Fabrication takes place in a robotic construction cell, where the entire workflow — from reinforcement measurement to formwork production — is digitally controlled. The actual reinforcement cage is first measured using laser-tracking technology to create an accurate as-built digital twin. This data is then used to design and manufacture customised formworks, including complex internal cavity moulds produced through 3D printing.

Multiple formwork strategies are explored, including reusable and recyclable thermoplastic moulds and printed mortar formworks, balancing material efficiency, reuse potential, and industrial feasibility. Sensors are embedded into selected beams, enabling structural health monitoring (SHM) and continuous performance tracking once installed. The solution will be validated through the construction of full-scale 7-metre beams, including mechanical testing and real use in a footbridge installation. Data from embedded sensors will be transmitted to the cloud, supporting long-term monitoring, maintenance planning, and future retrofitting decisions.

By combining digital fabrication, structural optimisation, and smart monitoring, KER 4.1 demonstrates how concrete infrastructure can become lighter, cleaner, more precise, and digitally manageable, supporting the transition to sustainable, Industry 4.0 transport construction.

BENEFITS



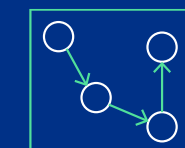
UP TO 40% REDUCTION IN CONCRETE USE THROUGH STRUCTURAL OPTIMISATION



LOWER CARBON FOOTPRINT AND REDUCED MATERIAL WASTE



HIGH PRECISION AND QUALITY CONTROL VIA DIGITAL FABRICATION



REDUCED CONSTRUCTION WASTE COMPARED TO CAST-IN-SITU METHODS



EMBEDDED MONITORING FOR LIFETIME PERFORMANCE TRACKING



EUROCODE-COMPLIANT AND MARKET-READY DESIGN APPROACH

ROADMAP TO IMPLEMENTATION

Digitise cavity positioning
(augmented reality glasses
for operators)

Improve the moulding
methodology to obtain two
clean surfaces

Use AI-assisted photogrammetry
methods for simpler
measurement of cages

Industrial pilot demonstrator
enabling manufacture of finalised
and competitive components

Apply to other typologies,
slabs, piles

Structural elements for sustainable TI

Low Noise & Low Vibration Ballasted Railway Track

CIRCULAR SOLUTIONS FOR QUIETER,
MORE DURABLE AND SUSTAINABLE
RAIL INFRASTRUCTURE

SECTOR 2 of 5
SUSTAINABLE ELEMENTS



Railways are already one of the most sustainable modes of transport, yet maintenance still requires large quantities of natural resources. One of the most critical components of a railway track is the ballast layer, which ensures load distribution, drainage, and track stability. Over time, ballast degrades due to particle breakage, abrasion, and contamination, which reduces track performance, increases noise and vibration levels, and leads to more frequent maintenance.

An innovative circular solution combines reused or low-quality ballast aggregates with scrap rubber derived from recycled waste tyres. These materials are integrated with shoulder elements and a geosynthetic reinforcement layer that provides lateral confinement to the ballast. Rubber particles act as a resilient interface between ballast grains, helping to absorb energy, reduce grain breakage, and dampen vibrations generated by passing trains.

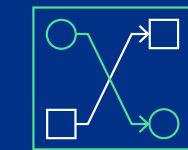
At the same time, the shoulder elements are mechanically connected by a planar geosynthetic reinforcement layer that acts as a tensile tie, increasing grain confinement and limiting permanent movement and rotation of the ballast grains without interfering with standard railway maintenance operations. This enhanced ballast system

also delivers performance improvements. By slowing ballast degradation, it helps maintain track geometry over longer periods and reduces the frequency of maintenance and associated costs. The elastic properties of recycled rubber reduce noise and vibration emissions, while the shoulder elements can also serve as a foundation for additional low-height noise barriers located close to the source. Together, these improvements enhance passenger comfort and reduce disturbance to nearby communities.

A comprehensive assessment programme and laboratory testing evaluates mechanical behaviour, abrasion resistance, stiffness, and friction properties of the modified ballast. Additional testing addresses critical safety and environmental aspects, including fire behaviour, combustibility, and the potential leaching of pollutants or microplastics. Large-scale physical models and numerical simulations are used to further optimise the design before final field validation.

By upgrading reused materials instead of discarding them, the solution transforms ballast from a waste stream into a high-performance resource. It demonstrates how circular materials, geosynthetics, and smart engineering can work together to deliver quieter, more durable, and more sustainable railway infrastructure.

BENEFITS



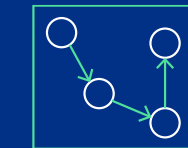
REDUCED NOISE AND VIBRATION THROUGH RUBBER-ENHANCED BALLAST BEHAVIOUR



EXTENDED BALLAST SERVICE LIFE BY REDUCING ABRASION AND GRAIN BREAKAGE



REUSE OF DEGRADED BALLAST, REDUCING DEMAND FOR VIRGIN AGGREGATES



IMPROVED TRACK STABILITY VIA LATERAL CONFINEMENT



LOWER MAINTENANCE REQUIREMENTS AND COSTS



ALIGNMENT WITH CIRCULAR ECONOMY PRINCIPLES AND SUSTAINABILITY GOALS

ROADMAP TO IMPLEMENTATION

Analyse sections to identify locations that could benefit from the installation

Define and communicate technical requirements for rubber aggregates

Present and promote the benefits of the solution to railway authorities

Adapt existing technical specifications for ballasted railway tracks

Support standardization and ensure interoperability with existing infrastructure

Demonstrate replicability across diverse environments and locations



LIAISON

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