

LIAISON

Standardising Smart Low-Carbon Infrastructure

POLICY RECOMMENDATIONS FOR GEOPOLYMER CONCRETE, SMART PRECAST
SYSTEMS AND DIGITAL STRUCTURAL MONITORING IN EUROPE



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Executive Summary

The European Union has committed to achieving **climate neutrality by 2050** while accelerating the digital transformation of transport infrastructure. Achieving these objectives requires construction materials and infrastructure systems that simultaneously reduce greenhouse gas emissions, improve resource efficiency, and enable data-driven asset management. However, current European standards and regulatory frameworks remain largely based on conventional Ordinary Portland Cement (OPC) concrete and prescriptive design approaches that do not adequately support emerging low-carbon materials or digitally enabled infrastructure.

The **LIAISON** project demonstrates that **innovative geopolymers concrete, modular precast pavement systems** and **embedded Structural Health Monitoring (SHM) technologies are sufficiently mature for wider deployment**. Full-scale demonstrators validated structural performance, durability, digital monitoring, and lifecycle benefits under realistic operating conditions. Environmental assessments further showed substantial reductions in embodied carbon while maintaining structural performance comparable to conventional concrete solutions.

Despite this technological maturity, **regulatory and standardisation gaps continue to impede market uptake**. Immediate action is required from the European Commission, CEN and CENELEC to update standards, certification schemes and procurement frameworks. Specifically, policymakers should:

- create harmonised provisions for geopolymers and alkali-activated materials;
- establish certification pathways for sensor-integrated infrastructure components;
- promote lifecycle-based procurement and digital asset management.

These measures would enable rapid deployment of validated low-carbon infrastructure solutions and support the objectives of the European Green Deal, Climate Law and Digital Decade.

Context

The European construction sector is responsible for a significant share of greenhouse gas emissions and raw material consumption. Cement production alone contributes approximately 7–8% of global CO₂ emissions, making decarbonisation of concrete one of the most important challenges for sustainable infrastructure.

Innovative technologies have advanced rapidly, while European standards have evolved more slowly. Current design rules were developed primarily for OPC-based concrete and conventional reinforced structures. Consequently, infrastructure owners face uncertainty when considering innovative materials, even where technical evidence demonstrates equivalent or superior performance.

The LIAISON project identifies **four principal regulatory barriers**:

- absence of harmonised design provisions for geopolymer concrete;
- lack of certification frameworks for sensorised structural components;
- procurement practices that prioritise lowest initial cost rather than lifecycle value;
- limited recognition of digital quality assurance and structural health monitoring within existing standards.

These barriers increase investment risk and delay the market introduction of technologies that directly support the European Green Deal, Circular Economy Action Plan and Digital Europe objectives.

Why now?

Several EU initiatives create a unique opportunity to **update standards and procurement frameworks**. Ongoing Eurocode revisions, implementation of the European Climate Law, the Digital Decade Policy Programme and the Construction Ecosystem Transition Pathway all require practical solutions that reduce emissions while improving infrastructure performance.

LIAISON provides validated evidence that such solutions are ready for deployment, making immediate policy action both timely and feasible.

Standardisation Gaps

Gap 1 – Eurocodes

Eurocodes and pavement standards do not explicitly support alkali-activated materials (AAMs), despite the project demonstrating that geopolymer precast slabs satisfy structural performance requirements. In LIAISON, **geopolymer slab mixtures** achieved the required compressive strength, and all fourteen full-scale precast slabs also met compressive-strength requirements during production quality control. Durability testing further showed that geopolymer pavements can provide long-term durability comparable with conventional concrete while reducing maintenance requirements.

Gap 2 – Product Standards

Existing standards do not provide certification pathways for embedded sensing technologies. LIAISON successfully embedded **fibre-optic Weigh-in-Motion (WIM) sensors** into full-scale precast slabs and **Structural Health Monitoring (SHM) sensors** into optimized beams, validating their suitability for continuous structural monitoring both under laboratory and demonstrator conditions.

Gap 3 – Procurement

Procurement legislation still favours lowest purchase price rather than lifecycle value. The comparative assessment performed in LIAISON shows that although the geopolymer smart slab has approximately 36% higher initial CAPEX¹, it provides **lower lifecycle costs**² through predictive maintenance, reduced inspections and lower operational risks. Environmentally, the geopolymer slab achieves a score of 10 versus 3 for conventional OPC slabs owing to an approximately **78% reduction in CO₂ emissions**³, while maintaining equivalent structural performance.

Gap 4 – Digital Infrastructure

Current regulations do not recognise digital quality control sufficiently to reward precision manufacturing. The optimized beam developed within LIAISON combines topology optimisation, robotic fabrication and digital quality assurance to reduce material consumption while maintaining structural reliability. Harmonising Eurocode Annex A provisions will allow digitally verified production to apply reduced partial safety factors ($\gamma_s = 1.10$ and $\gamma_c = 1.35$ where justified), enabling an additional **18% reduction in structural mass**⁴. Combined with topology optimisation, this creates a pathway towards approximately **40% material dematerialisation**⁵ without compromising structural reliability.

1 Cfr LIAISON Deliverable 2.5 Pilot Case of Industrialized Components for Road

2 Ibidem

3 Ibidem

4 Cfr LIAISON Deliverable 2.3 Design of the optimized smart beam

5 Cfr LIAISON Deliverable 2.5 Pilot Case of Industrialized Components for Road

Recommendations

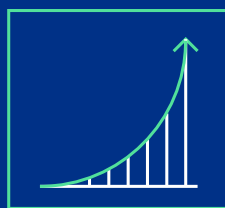
Recommendation	Evidence from LIAISON
Develop a Eurocode Technical Specification or Annex for geopolymer pavements and performance-based design	Full-scale geopolymer slabs satisfied compressive-strength and durability requirements while substantially reducing embodied carbon
Revise EN 13877 to include Alkali-Activated Materials and performance criteria	Project validated geopolymer pavements under laboratory and demonstration conditions
Establish European certification for Smart Structural Components integrating sensors	Successful embedding and validation of WIM and SHM sensors in pavements and beams
Extend CE marking to include sensor reliability, interoperability and long-term data quality	Chapter 5 identifies the absence of certification pathways for sensorised concrete products
Mandate lifecycle assessment, lifecycle costing and Environmental Product Declarations in public procurement	Smart geopolymer solutions provide around 78–80% lower CO ₂ emissions together with improved lifecycle performance
Introduce Green Public Procurement incentives for low-carbon and digitally monitored infrastructure	Carbon Premium, Green Premium and Dematerialisation Index are proposed in Chapter 5
Standardise data-driven maintenance using SHM and WIM	Demonstrator validated predictive monitoring and embedded sensing technologies

Actions

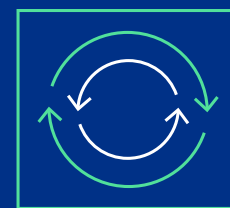
- **Short-term actions (1–3 years)**
 - Develop a CEN Technical Specification for geopolymer pavements.
 - Launch certification framework development for smart structural components.
 - Include lifecycle costing requirements in public procurement guidance.
- **Medium-term actions (3–7 years)**
 - Revise EN 13877 to include AAMs.
 - Extend CE Marking requirements to cover sensors and data quality.
 - Standardise SHM- and WIM-based maintenance practices.
- **Long-term actions (7+ years)**
 - Integrate geopolymer design provisions into future Eurocode revisions.
 - Establish harmonised European frameworks for digital infrastructure management.

Expected Impacts

Implementing these recommendations would deliver multiple benefits:



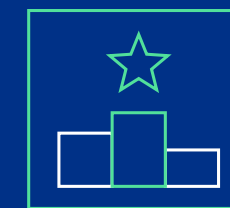
ACCELERATED MARKET
UPTAKE OF LOW-CARBON
CONSTRUCTION MATERIALS



IMPROVED DURABILITY,
RESILIENCE OF TRANSPORT
INFRASTRUCTURE



GREATER
LIFECYCLE
COST EFFICIENCY



STRONGER EUROPEAN
LEADERSHIP IN SUSTAINABLE
CONSTRUCTION TECH



SIGNIFICANT REDUCTIONS
IN EMBODIED GREENHOUSE
GAS EMISSIONS



ENHANCED DIGITAL
MONITORING AND
PREDICTIVE MAINTENANCE



INCREASED
CONFIDENCE AMONG
STAKEHOLDERS

LIAISON demonstrates that while smart geopolymer solutions may require higher initial investment, they **reduce lifecycle costs** through predictive maintenance, fewer inspections, lower disruption costs and longer service life.

Wider deployment would also **strengthen European competitiveness** in advanced construction materials, digital infrastructure technologies and smart manufacturing.

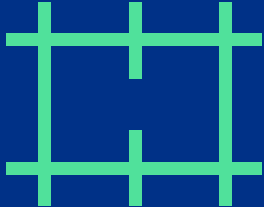
Conclusions

The technology is ready: full-scale demonstrators validated geopolymer precast systems and embedded monitoring technologies under realistic conditions.

Geopolymer solutions achieved approximately **78–80% lower embodied CO₂ emissions** than conventional OPC-based alternatives while maintaining required structural performance.

Standards now need to catch up and evolve towards performance-based, technology-neutral approaches that recognise low-carbon materials and digital infrastructure.

European action is essential to remove regulatory barriers, support industrial uptake and contribute directly to the objectives of the European Green Deal, the Circular Economy Action Plan and the Digital Decade.



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