Innovating for Longevity: Transformative Approaches to Bridge Maintenance:

Graham Stanford
Technical Director Volkerlaser

We must start by saying:

- Bridges age
- Demands grow
- Traditional maintenance methods are proving insufficient and often inadequate

There is a need to change

However, very often repair processes are what they are,
and innovation has to consider how we approach the subject of maintenance

Innovation has to consider:

- Modern technology,
- Materials science, and
- Data-driven approaches to extend the lifespan of bridges,
- Cost optimisation

Traditional methods, while effective, are often reactive. We need to adopt transformative, forward-looking strategies to ensure long-term resilience and safety.

However, let us not forget the Conrepnet study published in 2007 which made very similar points and noted that:

After 5 years 25% of repairs unsatisfactory
After 10 years 75% of repairs unsatisfactory
After 25 years 95% of repairs unsatisfactory

Reasons

- Growing urgency: Ageing bridge infrastructure globally
- The high cost of deferred maintenance - higher repair costs, closures, and catastrophic failures.
- Need for innovation in monitoring, materials, and maintenance strategies
- Climate Change: Rising temperatures, severe storms, and flooding intensify wear and accelerate degradation.
- Innovation is no longer optional—it's essential

(AP: Antonio Calanni Morandi bridge Genoa)

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Smart Monitoring and Predictive Maintenance

IoT sensors and real-time data collection

- Structural health monitoring (SHM)
- Use of embedded sensors Vibration, stress, corrosion
- Displacement sensors movement detection

AI and machine learning

- Predictive modelling for wear and failure
- Analysing sensor data to predict failures before they happen.
- Prioritising maintenance based on predictive risk models rather than inspection cycles. Data-driven maintenance scheduling

Case studies

- Success stories from smart bridges around the world

Bridge Asset Monitoring | MISTRAS Group

When steelwork defects forced the Forth Road Bridge to close, Amey used smart data capture to safeguard the iconic bridge's future.

"The FRB's system is currently world-leading and many bridge owners and maintainers around the world have visited the bridge to learn about how its life is being extended."

New Civil Engineer
2019

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Advanced Materials for Durability

- Ultra-high-performance concrete (UHPC)
- Self-healing materials (R3 move to R4?)
- Corrosion-resistant composites and coatings
- Retrofitting with FRP (fiber-reinforced polymer)

Top image courtesy of Freyssinet website

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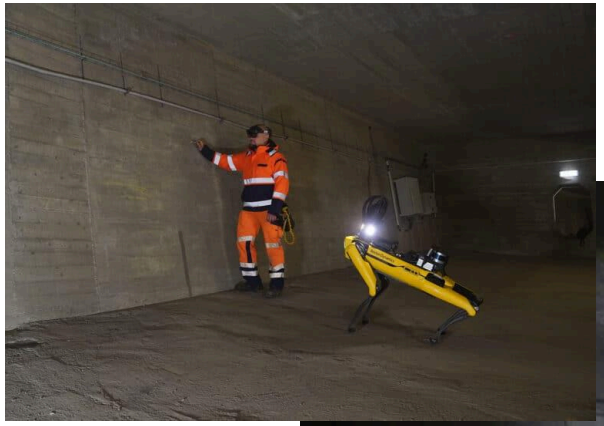
Robotics and Automation in Inspection & Repair

- Drones for visual inspections
- High-resolution imagery, thermal scans
- Robotic crawlers for hard-to-reach areas
- Automated maintenance systems
- Crack sealing, painting, debris removal
- Software that translates visual data into actionable maintenance recommendations and use of AI to speed this process up

Digital Innovation Transforms Historic Bridge Inspection

Robert Street Bridge shown highlighted with digital road markings after an inspection. Image courtesy of Collins Engineering.

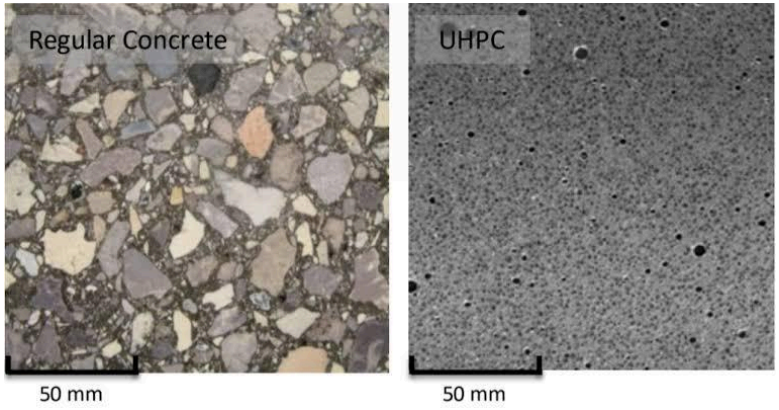


Critical Infrastructure: Spot Inspects Hamburg Bridge

Other issues:

Sustainability and Environmental Integration

- Eco-friendly de-icing methods
- Permeable bridge decks
- Reducing lifecycle emissions through longer-lasting materials



Lifecycle Cost Analysis and Funding Innovation

Digital Twins and Lifecycle Modelling

Policy and Regulatory Evolution: Performance-Based Contracts: Incentivize long-term durability rather than short-term fixes

Future Vision

- Integration with smart city infrastructure
- Next-generation maintenance with autonomous systems

Transformative bridge maintenance is about seeing the future and acting in the present

But all in all, we can say that innovation isn't just about one particular thing, but it is about how we:

- introduce new ideas,
- methods
- products

Especially those that are more effective or efficient than existing ones