Digital Roads Prosperity Partnership
Physical Theme

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Maintaining highway infrastructure is essential for safety and efficiency, yet traditional repair methods are often reactive, costly, labour-intensive, and disruptive to traffic flow. The **Digital Roads Prosperity Partnership** aims to revolutionise highway maintenance by integrating advanced physical and digital technologies.

Digital Roads consists of three interconnected themes: Physical, Digital, and Impact

The **Physical Theme** is developing an **Autonomous Maintenance Plant (AMP)** for highway repair. This initiative focuses on three key research tasks: Development of enhanced physical and digital repair materials; Development of physical and digital robotic crack repair processes; and Development of the digital AMP concept processes. Through the AMP, in collaboration with the Digital and Impact themes, we will achieve faster and more effective pre-emptive road maintenance leading to less disruptions and the extended lifespan of highway infrastructure and enhancing road safety.

Development physical and digital enhanced repair materials

This work investigates the development of enhanced concrete road repair materials by adding various fibres to two commercial products: Rapid Set (cementitious) and Road Mender (polyurethane). We tested the enhanced materials for extrusion and crack fillability into 3 and 6 mm cracks, mechanical performance through flexural, and compression tests, and effectiveness as repairs using three-point bending (Fig. 1a) and slant shear on concrete with 6 mm cracks. For example, RS enhanced with 0.6% polyvinyl alcohol fibres (1–2 mm in length) demonstrated as a repair under flexure, a 30% increase in ultimate strength and toughness, twice the ductility compared to plain RS (Fig 1b), leading to potentially more durable repairs—extending repair lifespan and reducing maintenance costs.

Flexural test of repair Fig. 1 b) **Flexural repair data**

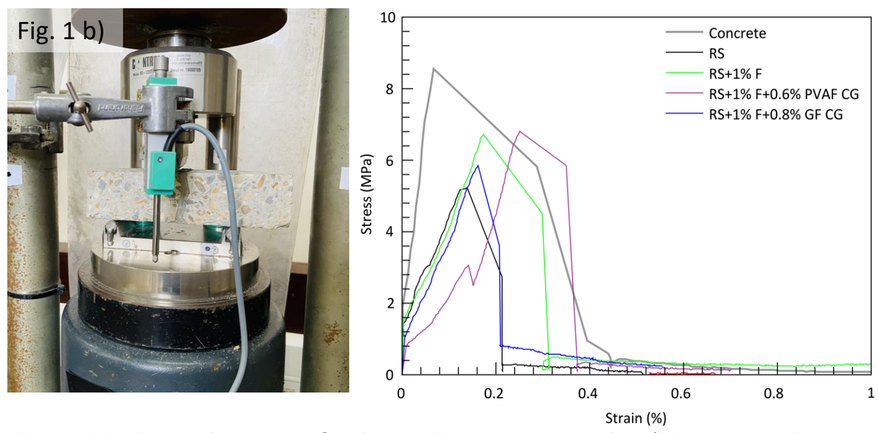

Fig. 1. Mechanical testing of enhanced repair materials: a) Commercial repair materials; a) Flexural test to measure the flexural (bending) strength, properties of the materials; and b) Plot showing the flexural properties of representative materials composed of Rapid Set and fibre additions.

Development of physical and digital robotic crack repair processes

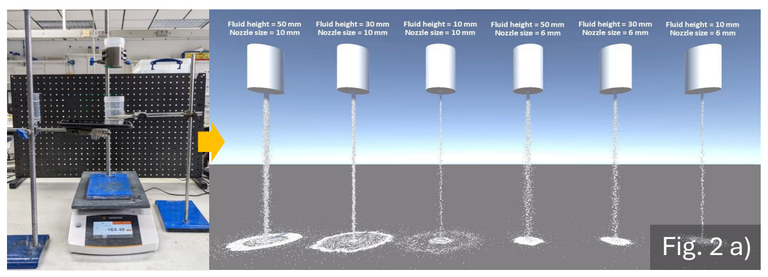

Fig. 2 a)

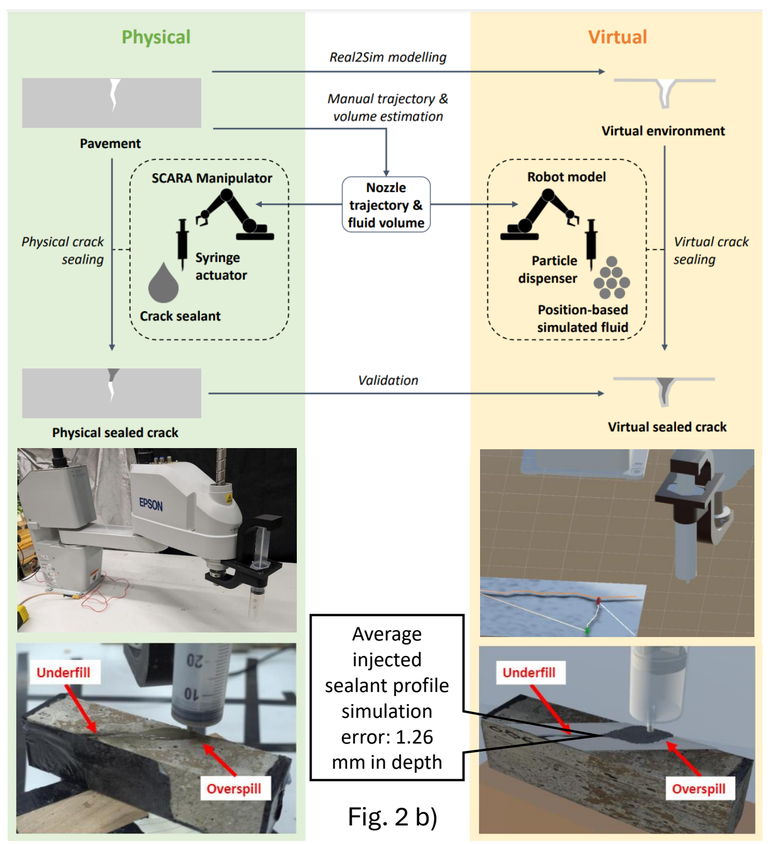

Fig. 2 b)

Fig. 2 Position-based Fluid simulation to inform physical robotic crack sealing operations: a) Transfer the physical sealant flow behaviour to simulated sealants using an agile flow cup test; and b) Map the simulated robotic crack sealing process (using the learned sealant flow behaviour) with the reality in the lab.

Develop the digital AMP concept

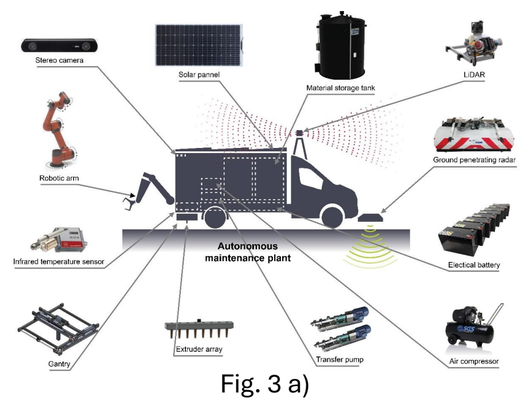

Fig. 3 a)

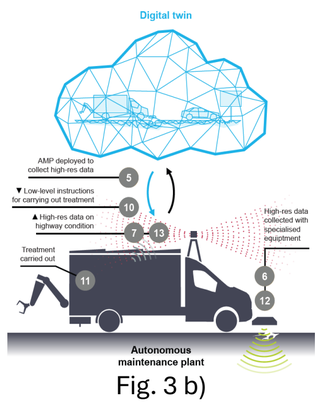

Fig. 3 b)

Fig. 3 c)

Fig. 3 Conceptual Autonomous Maintenance Plant (AMP) system for autonomous pavement crack repair: a) AMP system composition, mainly consisting of five modules for sensing, actuation, control, power supply and mobility; b) Digital workflow of the AMP including high-resolution surface sensing and autonomous crack repair operations, enabled (instructed) by the road digital twin; and c) different views of the AMP system in Unity simulation.

What next?

Plan for the coming 12 months:

- Develop low-hanging fruit proof-of-concept enhanced asphalt road repair materials
- Verified durability of repaired defect samples
- Establish fast sealant fluid fillability benchmarking test using simulation
- Automated crack trajectory planning and following
- Integrate the conceptual AMP systems with robotic repair mechanism

Acknowledgements

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