Crack Identification & Monitoring

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CTI Engineering & Waterman Group

- Waterman Group is a multidisciplinary consultancy providing sustainable solutions to meet the planning, engineering design and project delivery needs of the property, infrastructure, environment and energy markets.

- Waterman Group is part of CTI Engineering, the leading Japanese engineering consultancy. CTI provides professional consulting services related to civil engineering and construction works, including planning, research, design, and project management.

- It is CTI's innovative research in conjunction with Fujitsu which has lead to some of the technologies I will be talking about today.

Atsushi Kuzuno

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Richard Brooks

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Highway Structures & Bridges
Inspection & Assessment

CS 450
Inspection of highway structures

(formerly BD 63/17)

Highway Structures & Bridges
Inspection & Assessment

CS 451
Structural review and assessment of highway structures

(formerly BD 101/11)

Appendix A. Risk-based principal inspection intervals

A1 Risk-based principal inspection intervals

A1.1 Risk assessment procedure

This procedure outlines a suitable basis for the risk assessment of intervals between principal inspections as described in Section 8.

Identifying Cracking

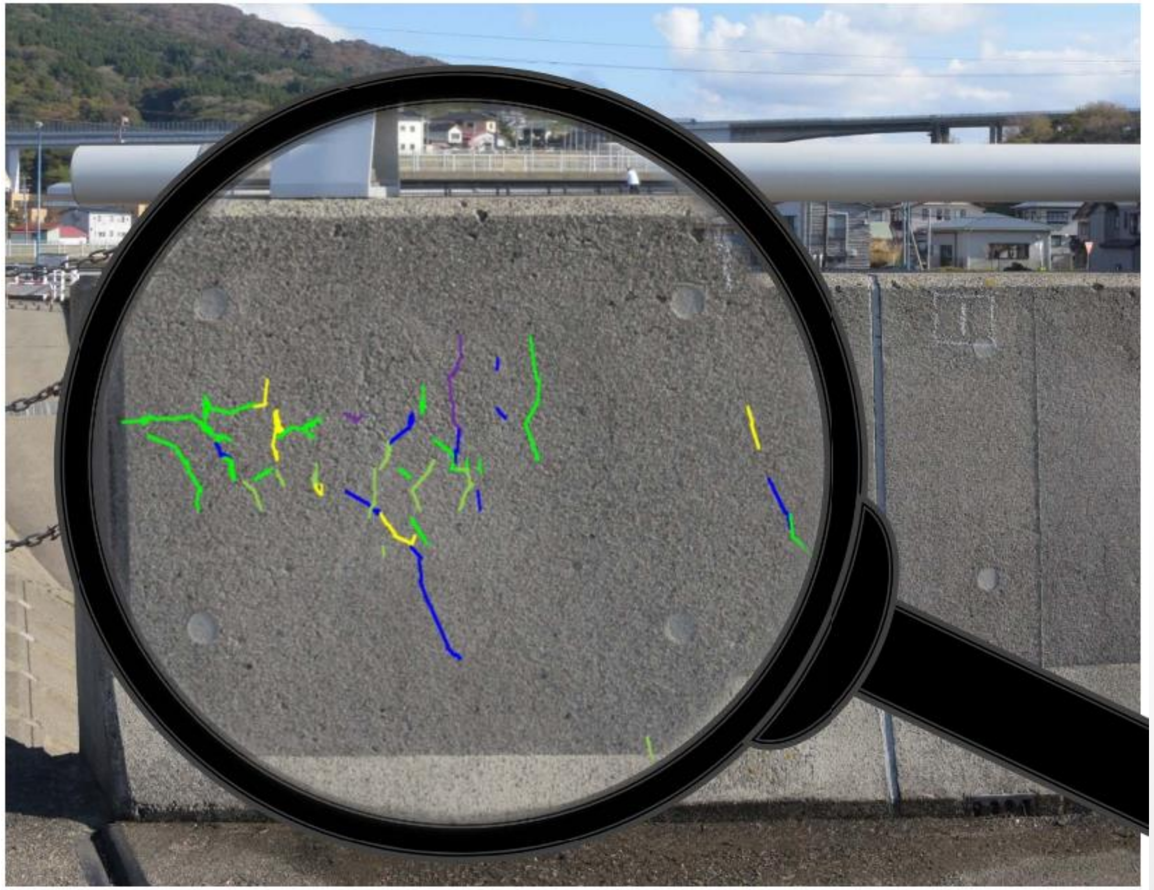
Cracking can be identified in a number of ways depending on the type of construction. Typical indicators to look out for whilst undertaking inspections can include the following;

Damp and staining, Corrosion, Movement

AI Detection involves the use of AI technology to automatically detects cracks using photographs of structures.

Cracking to Structures

One of the biggest problems affecting bridges is the cracking and deterioration of the bridge decks. The causes of cracking are primarily through thermal cracking or movement in the structure.



Cracking to Structures

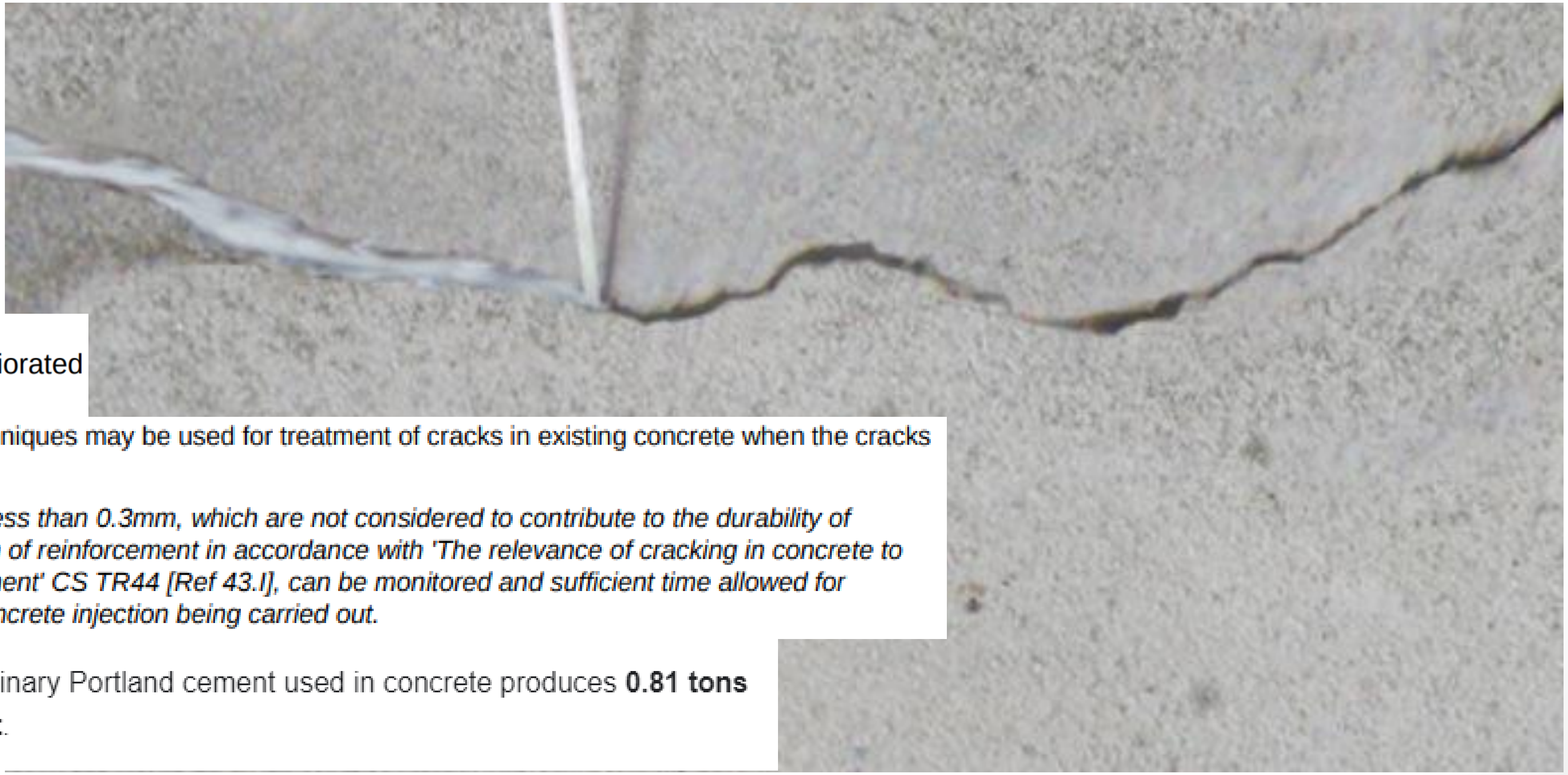
1. Diagonal Cracks
2. Horizontal Cracks
3. Splitting Cracks
4. Corrosion Cracks
5. Shrinkage Cracks
6. Expansion Cracks

Monitoring of Cracking

Observing changes in crack length and width is one of the techniques used to monitor structural deterioration, and there are several instruments used to monitor crack width changes.

Repair of Cracking in Concrete

Smaller cracks could be sealed instead of patched with resin materials. These primarily function by inhibiting water ingress into the structure for these smaller defects, and protect against deterioration as opposed to strictly 'repairing' the defect. Resin injection can be used to seal cracks as narrow as 0.3mm.



CS 462
Repair and management of deteriorated concrete highway structures

7.31.1 Concrete injection techniques may be used for treatment of cracks in existing concrete when the cracks are wider than 0.3mm.

NOTE *Fine cracks, typically less than 0.3mm, which are not considered to contribute to the durability of concrete and corrosion of reinforcement in accordance with 'The relevance of cracking in concrete to corrosion of reinforcement' CS TR44 [Ref 43.I], can be monitored and sufficient time allowed for self-healing prior to concrete injection being carried out.*

Manufacture and using of Ordinary Portland cement used in concrete produces **0.81 tons of CO_2 per 1 tons of cement**.

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Classification of Cracking

7.3 Crack control

7.3.1 General considerations

(1)P Cracking shall be limited to an extent that will not impair the proper functioning or durability of the structure or cause its appearance to be unacceptable.

(2) Cracking is normal in reinforced concrete structures subject to bending, shear, torsion or tension resulting from either direct loading or restraint or imposed deformations.

(3) Cracks may also arise from other causes such as plastic shrinkage or expansive chemical reactions within the hardened concrete. Such cracks may be unacceptably large but their avoidance and control lie outside the scope of this Section.

(4) Cracks may be permitted to form without any attempt to control their width, provided they do not impair the functioning of the structure.

(5) [AC1] A limiting value, w_{max}, for the calculated crack width, w_k, taking into account [AC1] the proposed function and nature of the structure and the costs of limiting cracking, should be established.

Note: The value of w_{max} for use in a Country may be found in its National Annex. The recommended values for relevant exposure classes are given in Table 7.1N.

BS EN 1992-1-1:2004
EN 1992-1-1:2004 (E)

Table 7.1N Recommended values of w_{max} (mm)

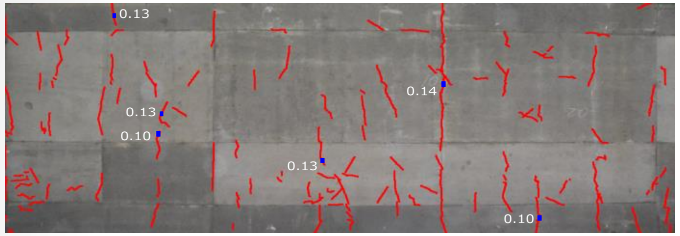
Exposure Class	Reinforced members and prestressed members with unbonded tendons	Prestressed members with bonded tendons
	Quasi-permanent load combination	Frequent load combination
X0, XC1	0,4[1]	0,2
XC2, XC3, XC4	0,3	0,2[2]
[AC2] XD1, XD2, XD3, XS1, XS2, XS3 [AC2]		Decompression

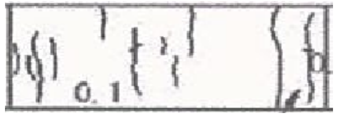
Note 1: For X0, XC1 exposure classes, crack width has no influence on durability and [AC1] this limit is set to give generally acceptable appearance. In the absence [AC1] of appearance conditions this limit may be relaxed.

Note 2: For these exposure classes, in addition, decompression should be checked under the quasi-permanent combination of loads.

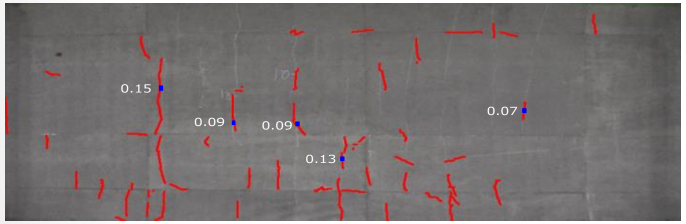
Use of A.I. Crack Identification

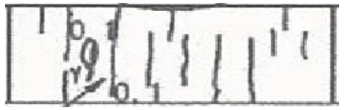
Samples of Cracks Detection Result





Damage diagram previously produced (by CTI)



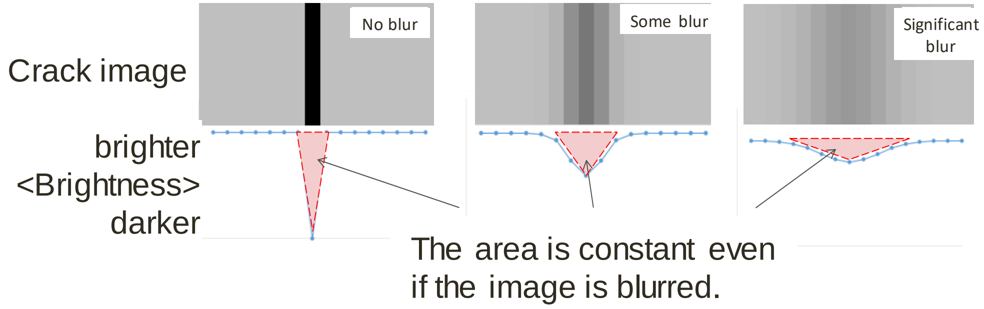


Damage diagram previously produced (by CTI)

Crack Measurement Technology (estimate the width)

<u>Calculation of crack width using luminance reduction amount which does not change even if image is blurred</u>

The crack width is calculated by our original model which relates the decrease in luminance with the crack width.



Original image

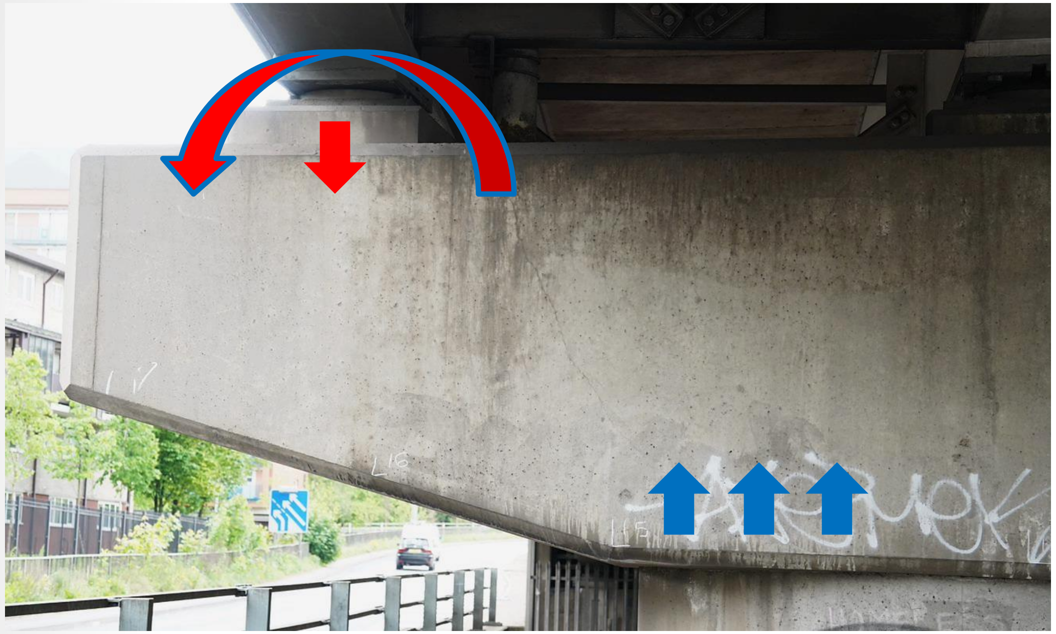
Tone corrected image

Original image

Potential cracks

Detection result

Monitoring of Cracking



1991 Steel Concrete Composite Structure with reinforced concrete crossheads supporting the bearings

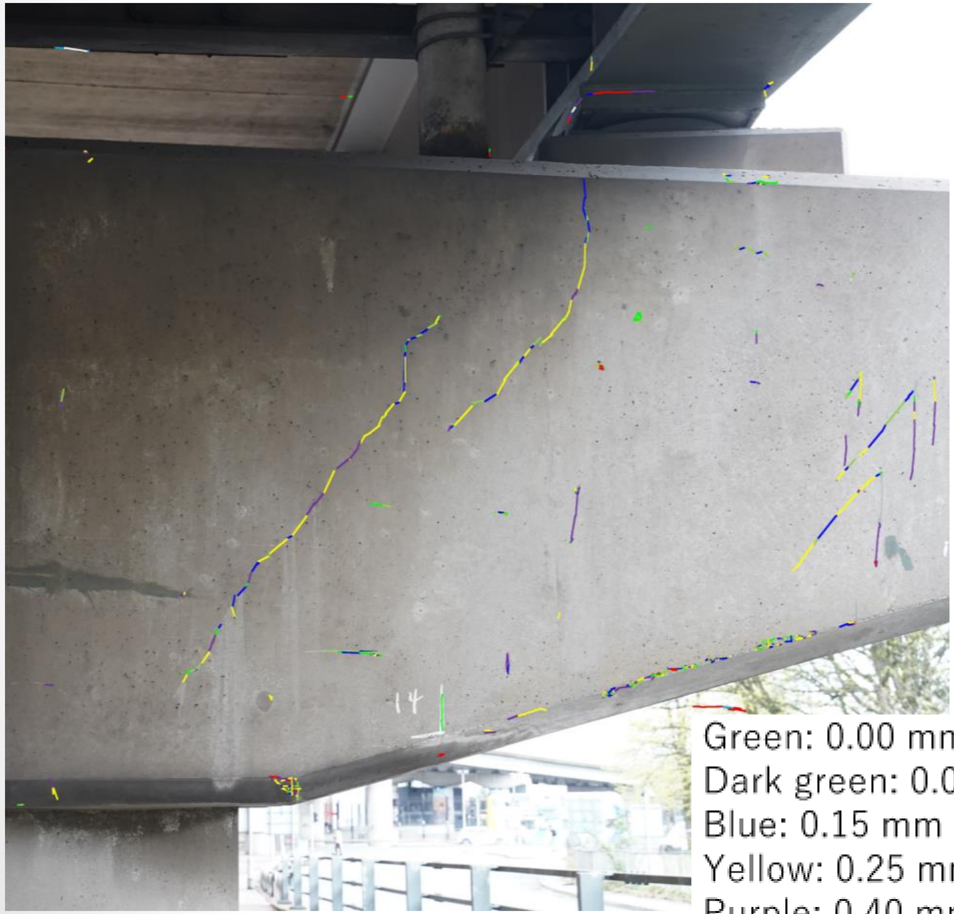
Cantilever to south bearing (pictured)

Cracking exhibited to cantilevered section of crosshead between the fixed support (blue arrows) and the point loading at the bearing (red arrow) due to Overturning Moment (red arrow, blue outline), cracking exhibited to both faces

Is this cracking static? Ongoing? What is the rate of progression?

Monitoring of Cracking

AI Crack Monitoring – Pier Crossheads



Green: 0.00 mm to 0.05 mm
Dark green: 0.05 mm to 0.15 mm
Blue: 0.15 mm to 0.25 mm
Yellow: 0.25 mm to 0.40 mm
Purple: 0.40 mm to 0.75 mm
Red: 0.75 mm to 1.50 mm
Light blue: 1.50 mm to 2.50 mm

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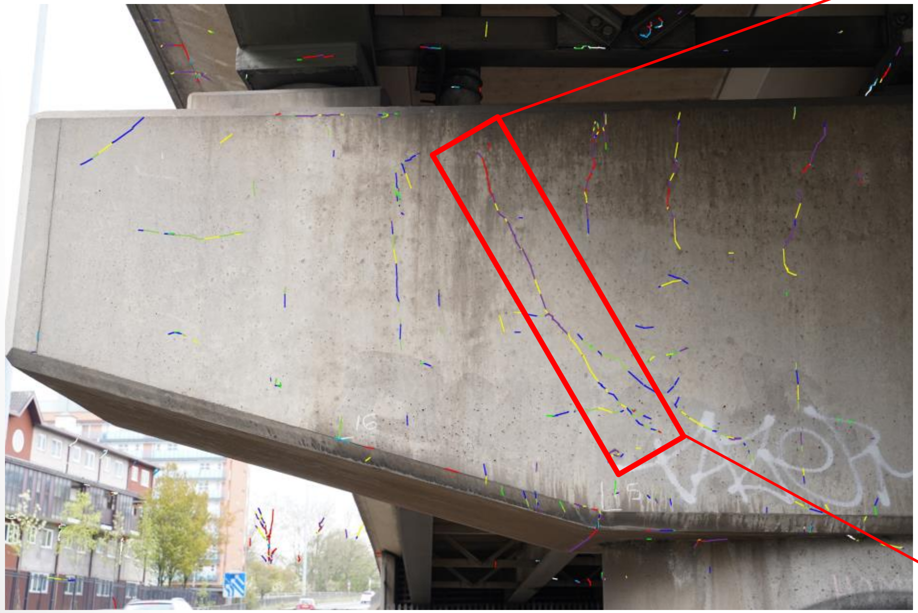
Monitoring of Cracking

The cracking is predominantly yellow and purple, with some red at the top and blue at the base. Interpreting these values tells us that the width of the crack varies as follows;

Top 0.15m = RED = 0.75 – 1.50mm

Central 0.75m = YELLOW / PURPLE = 0.25 – 0.75mm

Bottom 0.40m = BLUE / YELLOW = 0.15 – 0.40mm



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Yellow: 0.25 mm to 0.40 mm
Purple: 0.40 mm to 0.75 mm
Red: 0.75 mm to 1.50 mm
Light blue: 1.50 mm to 2.50 mm

Monitoring of Cracking

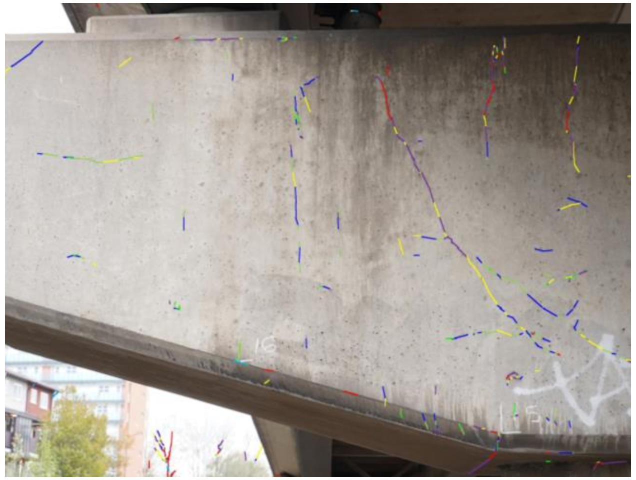
The top two photographs are taken with a 16MP camera at 4m distance

The bottom two photographs are taken with a 24MP camera at 8m distance

Green: 0.00 mm to 0.05 mm
Dark green: 0.05 mm to 0.15 mm
Blue: 0.15 mm to 0.25 mm
Yellow: 0.25 mm to 0.40 mm
Purple: 0.40 mm to 0.75 mm
Red: 0.75 mm to 1.50 mm
Light blue: 1.50 mm to 2.50 mm

16MP camera

Total length = 1.3m
Minimum width detected = 0.15mm
Maximum width detected = 1.50mm



24MP camera

Total length = 1.5m
Minimum width detected = 0.05mm
Maximum width detected = 1.50mm

Monitoring of Cracking

The top two photographs are taken with a 16MP camera at 4m distance

The bottom two photographs are taken with a 24MP camera at 8m distance

Green: 0.00 mm to 0.05 mm
Dark green: 0.05 mm to 0.15 mm
Blue: 0.15 mm to 0.25 mm
Yellow: 0.25 mm to 0.40 mm
Purple: 0.40 mm to 0.75 mm
Red: 0.75 mm to 1.50 mm
Light blue: 1.50 mm to 2.50 mm

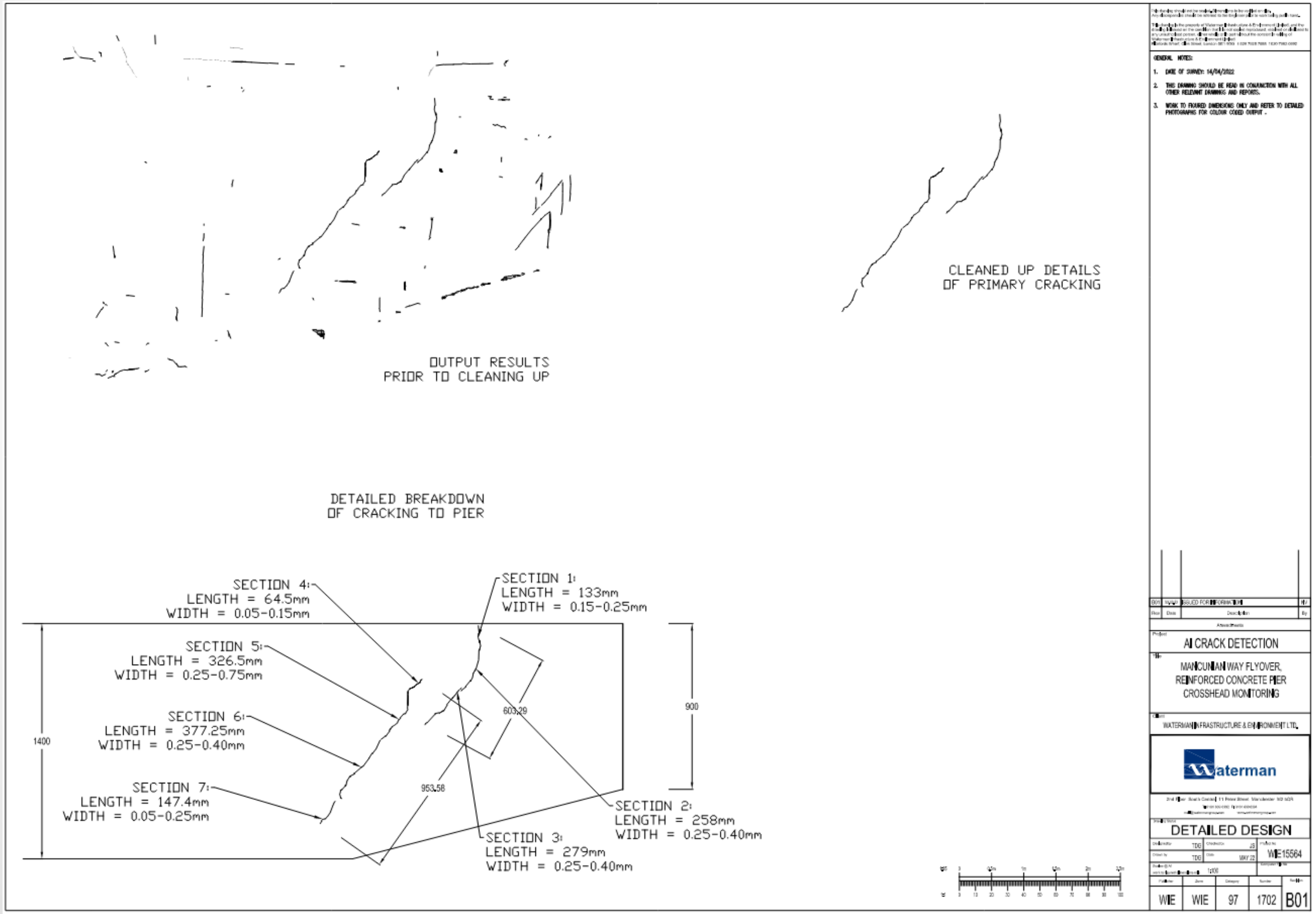
16MP camera

Total length = 1.2m
Minimum width detected = 0.15mm
Maximum width detected = 0.75mm

24MP camera

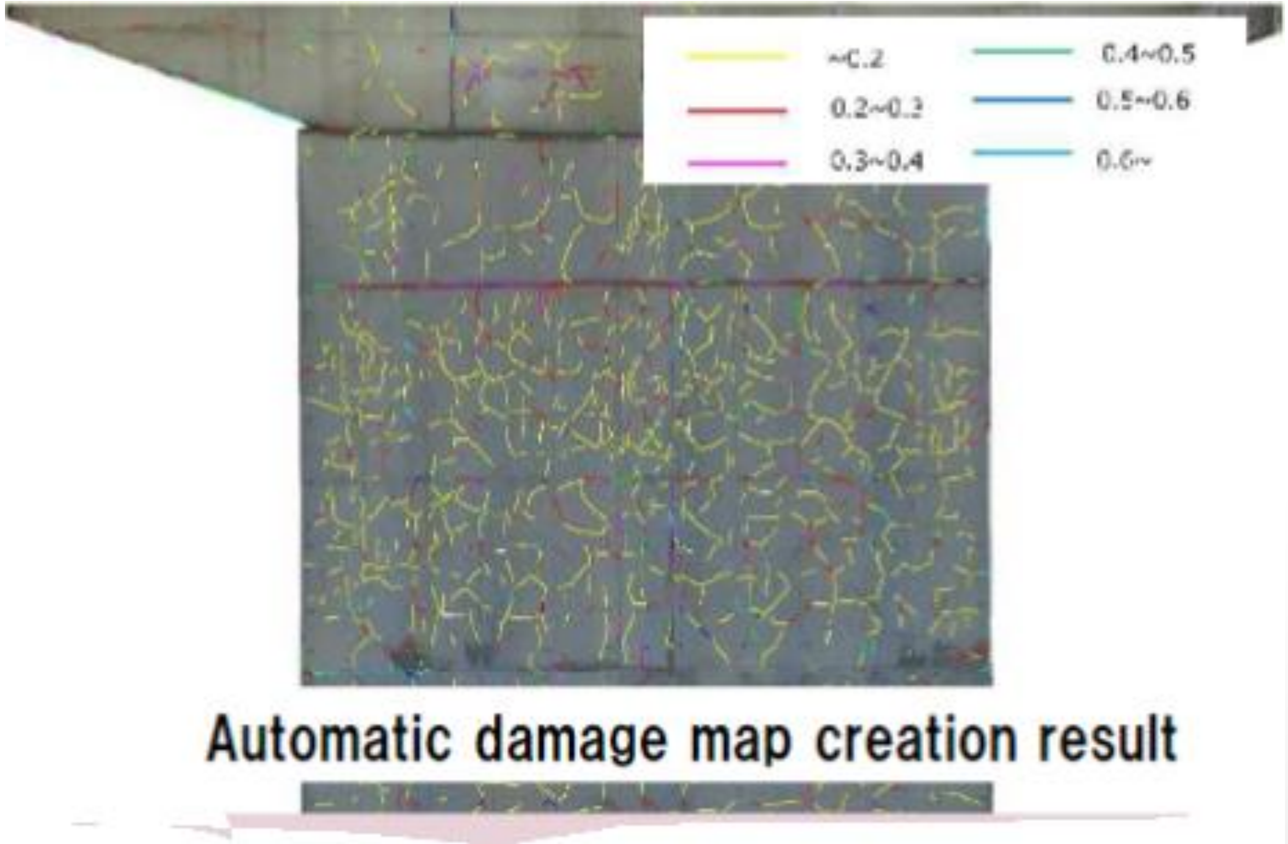
Total length = 1.65m
Minimum width detected = 0.05mm
Maximum width detected = 0.75mm

Monitoring of Cracking



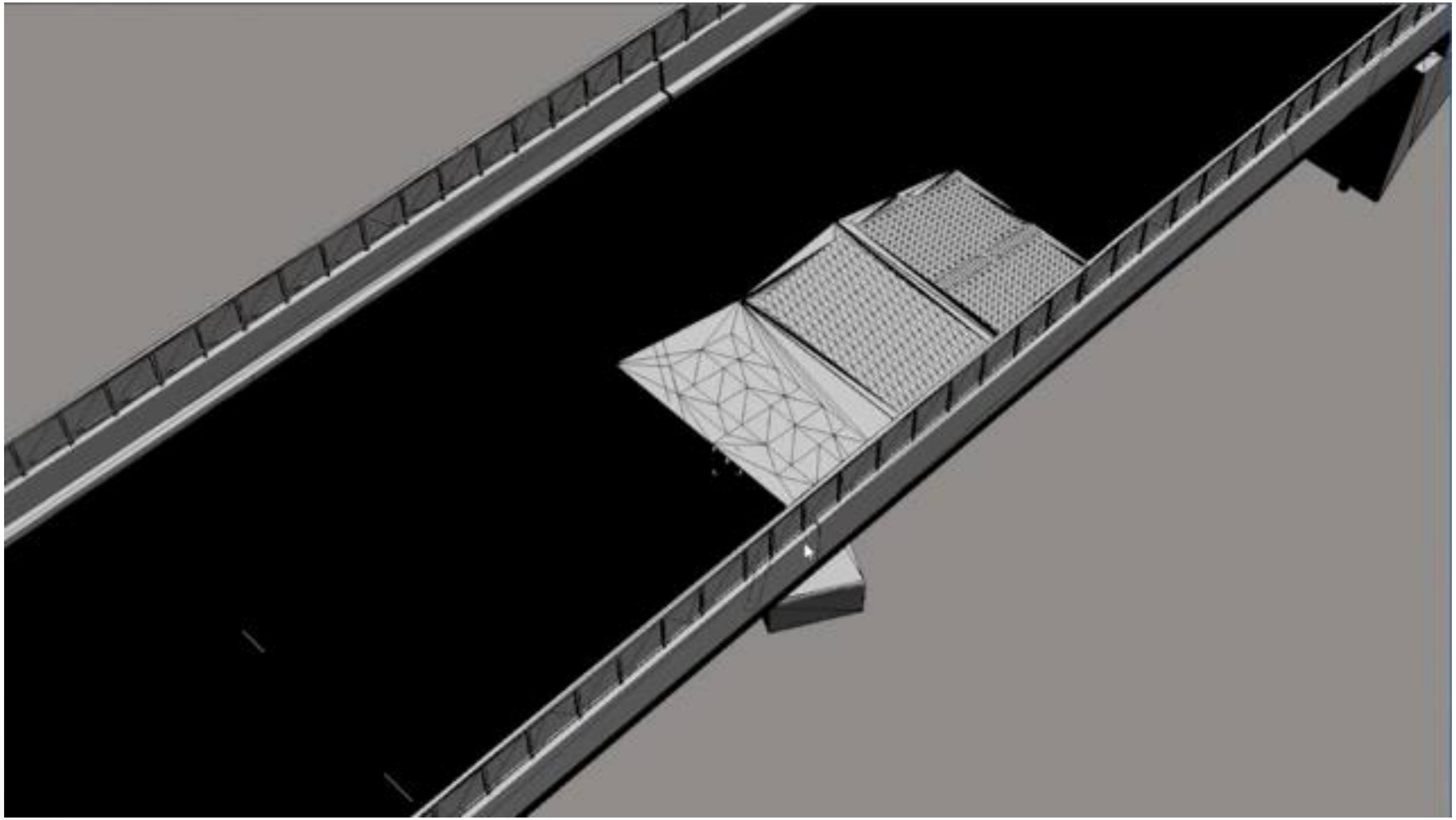
Additional Technologies

- AI Crack Investigation Technology can be undertaken from Camera or Drone



Automatic damage map creation result

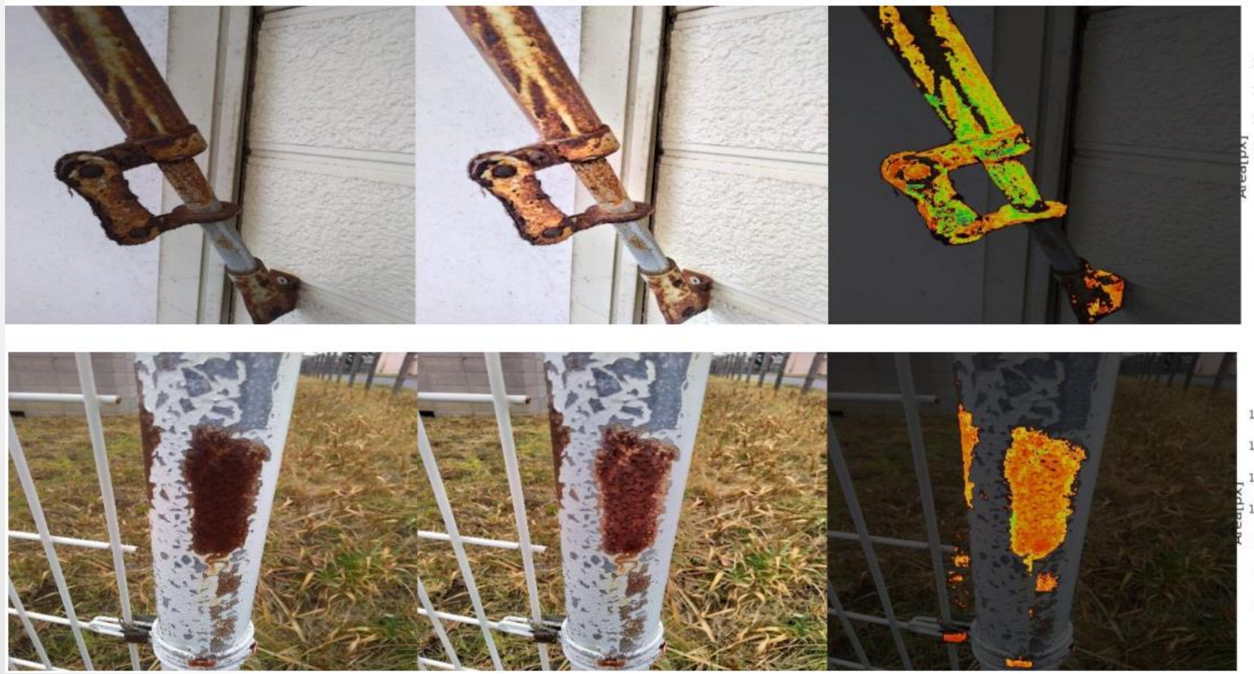
Additional Technologies

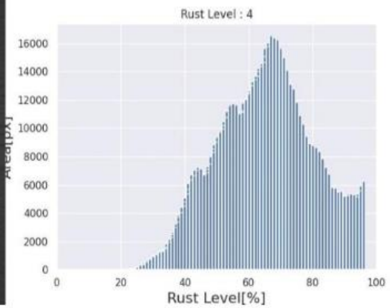


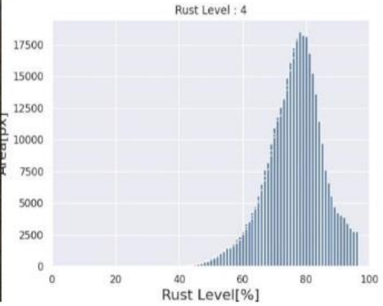
Additional Technologies

Additional Technologies

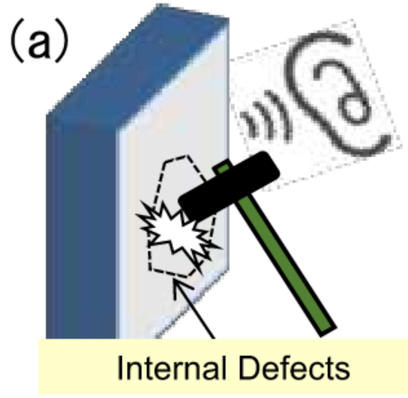
As well as scanning for defects, laser scanning systems can be used to identify areas of drummy or hollow concrete, using resonance and vibration to identify voiding.





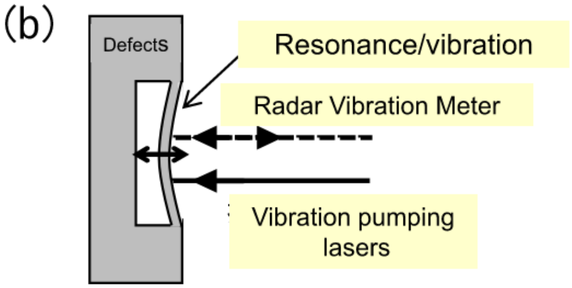


(a)Traditional method: hammering



Diagnosis based on the experience of experienced technicians

(b) Laser sound systems



From now on, quantitative diagnosis based on data!

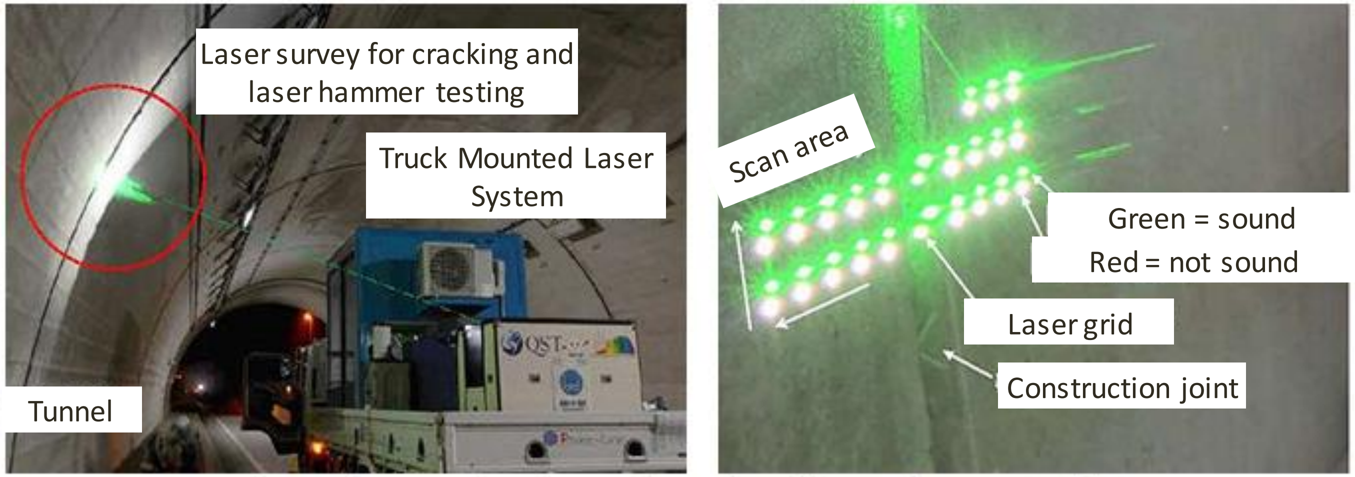
Additional Technologies

The laser hammering system was developed with a focus on tunnel concrete lining, but we will proceed to apply it to various other infrastructures and continue the development of safe and reliable inspection robots that eliminate reliance on human hands.

Current Inspection

Traffic Management required for closure and MEWP required for access

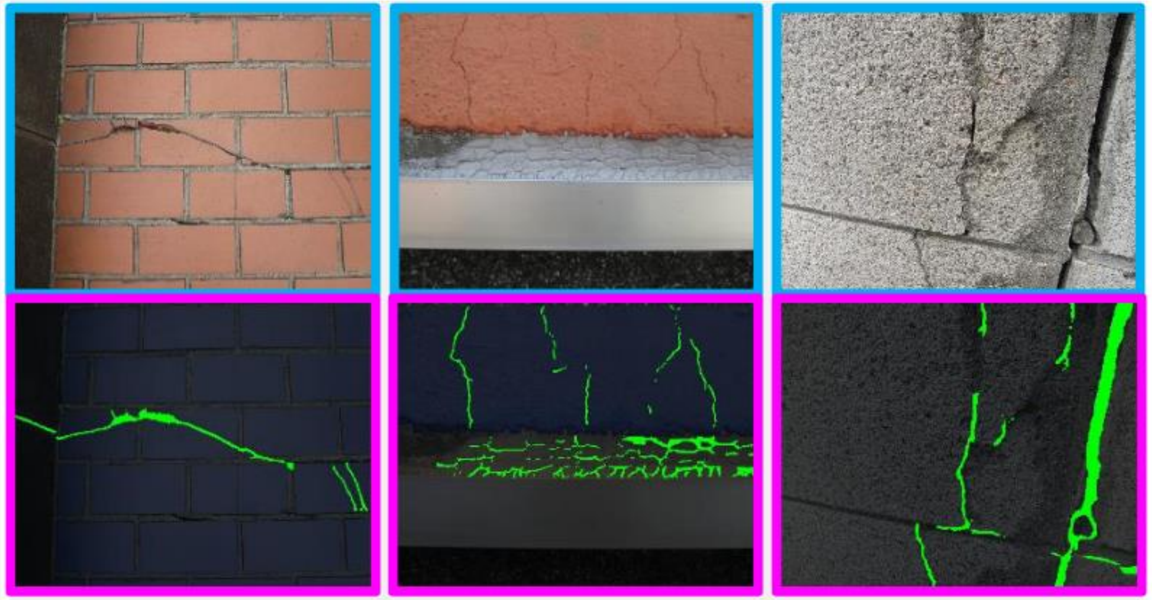
Future Inspection

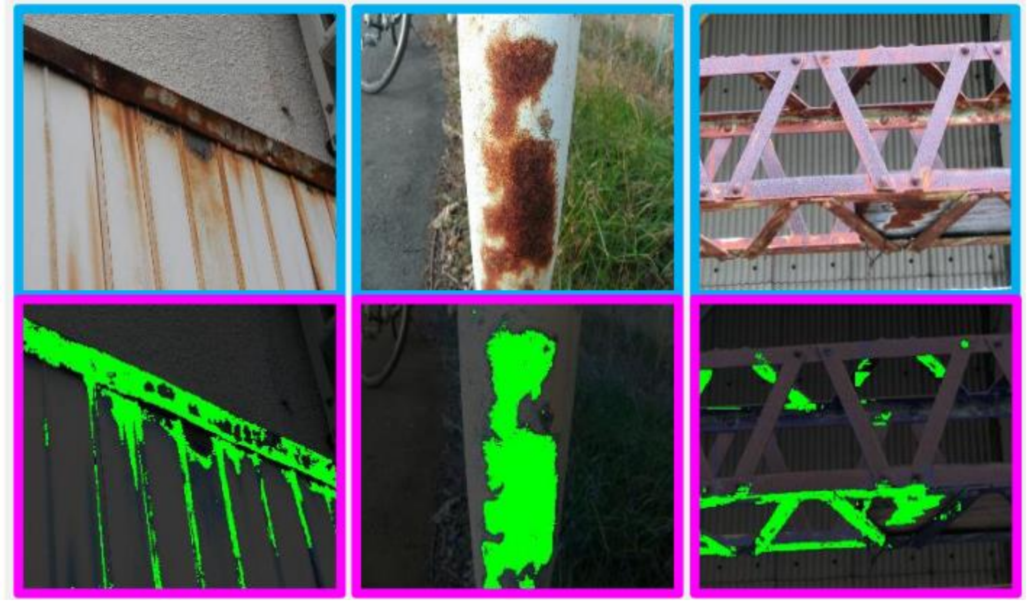


Laser hammering inspection of road tunnel concrete joints

The laser hammering system is a type of robotic inspection technology that assists inspection engineers during the periodic inspection of road tunnels.

Additional Technologies





The AI can also detect corrosion in metallic structures as well as cracking in concrete and masonry structures.

This adds another layer of accuracy onto inspection work, on top of the visual identification and any sounding works undertaken.

Cost & Carbon Reduction

Typical Costs:
Traffic Management – Road Closure - £1,000
MEWP of Scaffolding – Access - £750
Permits – Track Possession - £7,500
Safety Critical Staff Costs - £1,500
Site Personnel Costs - £1,500

Carbon footprint of works = High

Costs:
Site Personnel Costs - £1,500
AI Technology Costs – indicatively £5 per photograph quantity dependent

Carbon footprint of works = Low

Questions?

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