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Case Study – Fire Damage Repair of the Sarnia Road Bridge

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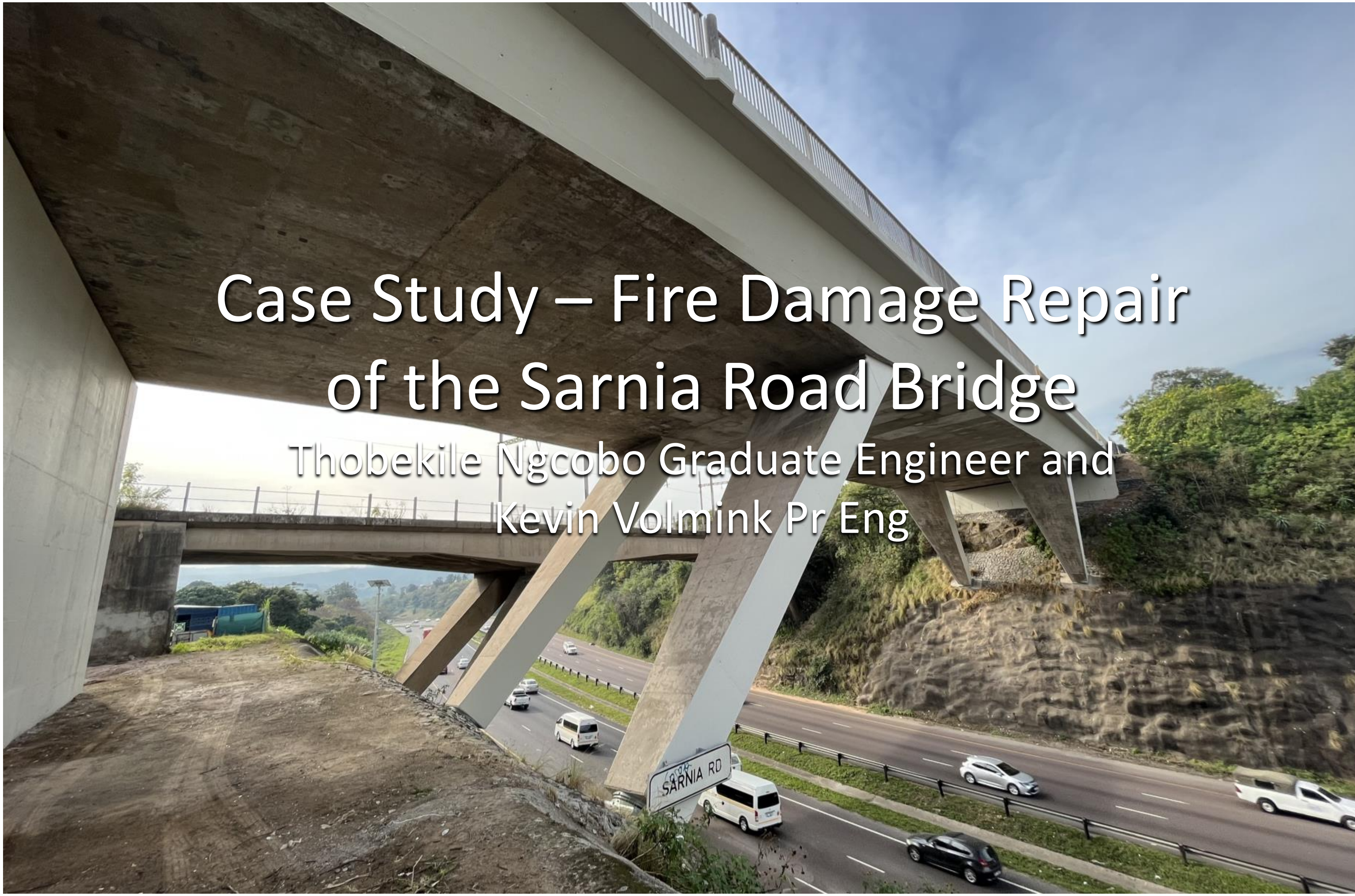

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Presentation Outline

- Introduction
- Structure Details
- Post-fire Assessment and Testing
- Conclusion on Fire Damage Response
- Access, On-site Assessment and Testing
- Repair Objectives and Methodology
- Repair Performance and Testing
- Objectives Achieved and Recommendations

Introduction

- Fire - a threat to infrastructure.
- Tankers transporting flammable fuels are the cause for most bridge fires.
- Damage to B112 – Sarnia Road Bridge

Structure Details - B112 Sarnia Road Bridge

- Rigid frame structure with inclined columns
- Deck: Post-tensioned concrete box girder (depths varying between 1.8m and 1.2m)
- Main span: 33.4m
- Two jack spans: 19.4m and 19.63m
- Simply supported post-tensioned box girder deck of 1.2m depth spans 16.57m over Palm Drive

Fire Damage - B112 Sarnia Road Bridge

- Petrol and diesel tanker collision in August 2015
- Type of fire and location
- Response and Details of damage

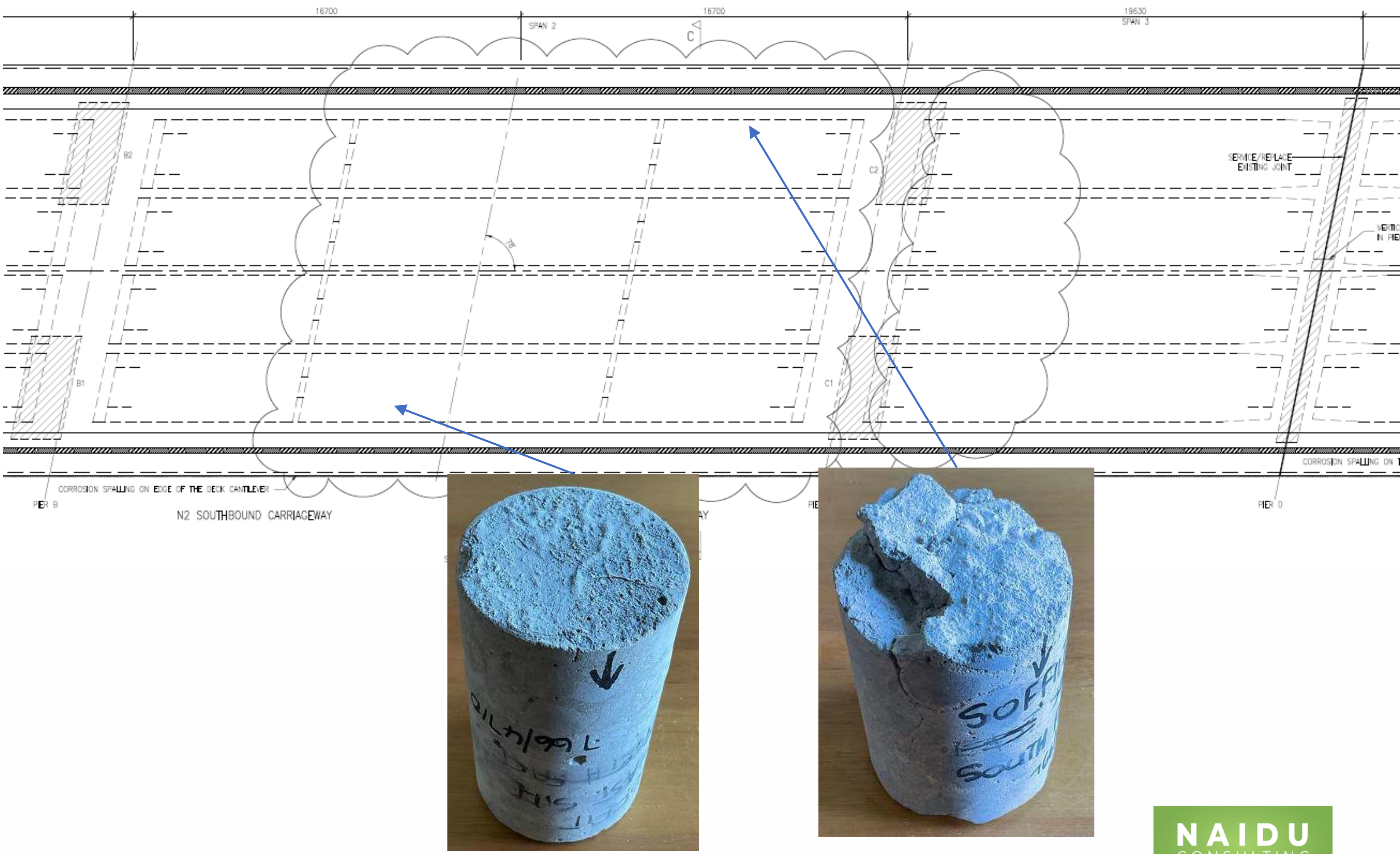
Post-fire Assessment

- Sarnia Road Bridge's damage classified as Damage Level 2 (Slight damage).
- Possibility of repair without replacing any structural elements.

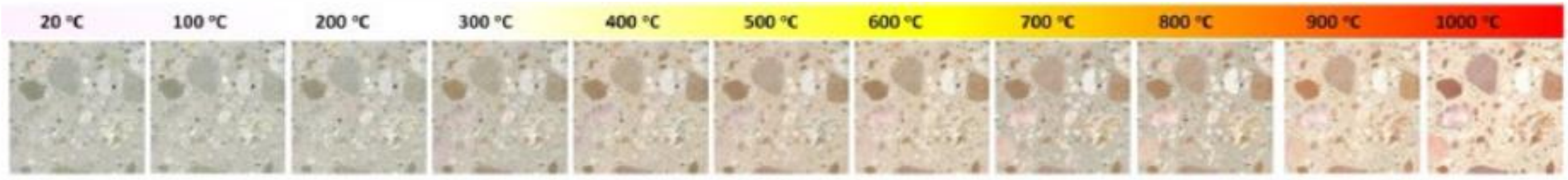
Visual Assessment of Fire Damaged Concrete

- Spalling identified on soffit and sides of the concrete box girder
- Exposure of reinforcement

Concrete Core Testing



Fire Impact on Concrete Colour



- Change in colour due to chemical and physical changes when exposed to high temperatures.
- Quartz-containing concrete turns pink/red between 300°-600°C.
- Discolouration near fire's location suggests exposure above 300°C.

Strength Assessment

<table>
<tr><th>Core Number</th><th>Core Location and Orientation</th><th colspan="2">Compressive Strength (MPa)</th><th>Microstructure</th></tr>
<tr><td>1</td><td>Deck, Soffit B, South Face (region subject to direct fire exposure)</td><td>36</td><td rowspan="3">41</td><td rowspan="3">Sound, below 35mm depth</td></tr>
<tr><td>2</td><td>Deck, Soffit B, South Face (region subject to direct fire exposure)</td><td>44</td></tr>
<tr><td>3</td><td>Deck, Soffit B, South Face (region subject to direct fire exposure)</td><td>43.5</td></tr>
<tr><td>4</td><td>Deck, Middle, West Side</td><td>46</td><td rowspan="3">46</td><td rowspan="3">Sound, below 20mm depth</td></tr>
<tr><td>5</td><td>Deck, Middle, West Side</td><td>45.5</td></tr>
<tr><td>6</td><td>Deck, Middle, West Side</td><td>46</td></tr>
<tr><td>7</td><td>Deck, North Face, East Side</td><td>46.5</td><td rowspan="3">47</td><td rowspan="3">Sound, below 2mm depth</td></tr>
<tr><td>8</td><td>Deck, North Face, East Side</td><td>47</td></tr>
<tr><td>9</td><td>Deck, North Face, East Side</td><td>46</td></tr>
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- Concrete remained unaffected beyond the depth of 35mm.

Carbonation and Chloride Ingress

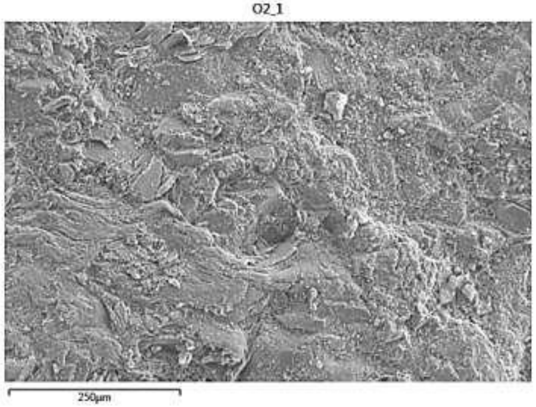
- More than 120m^2 of the surface area of the bridge was spalled off due to carbonation and chloride induced corrosion.

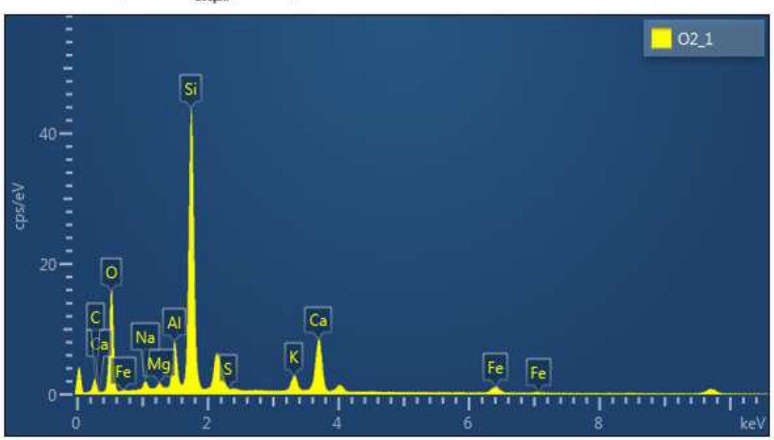


Microstructural Analysis

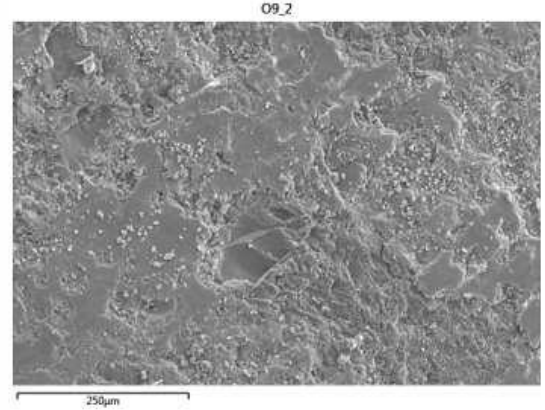
- Scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS).

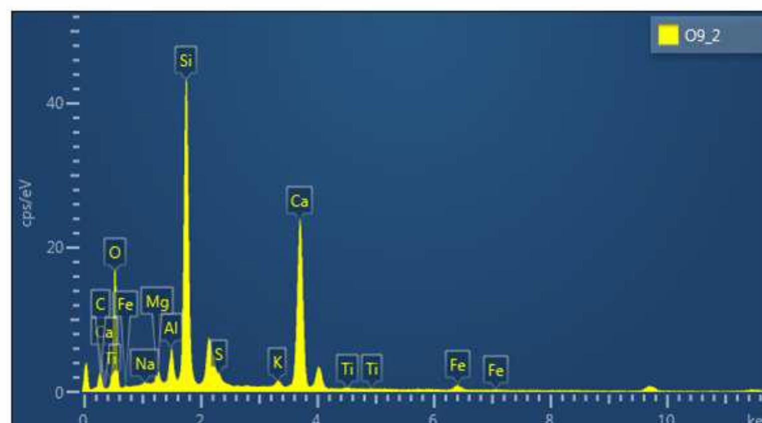
O2_1



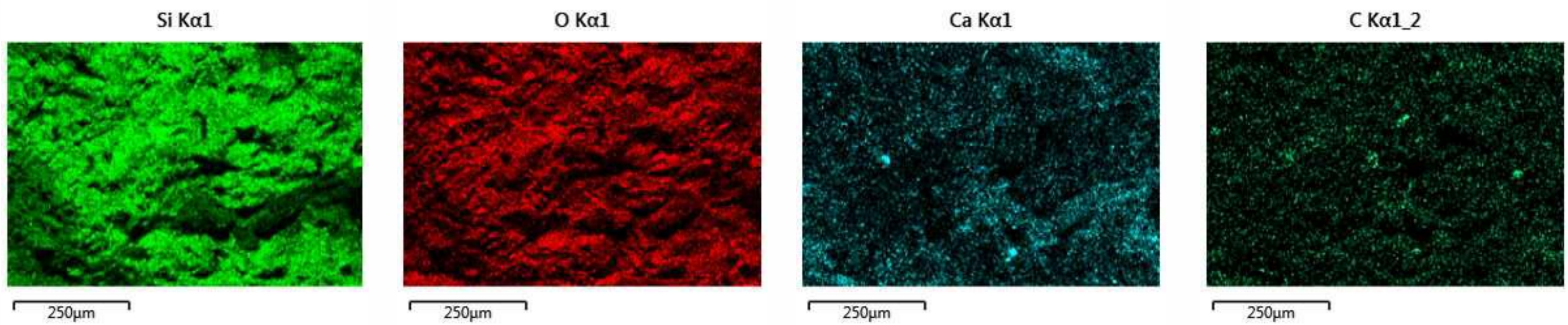


O9_2



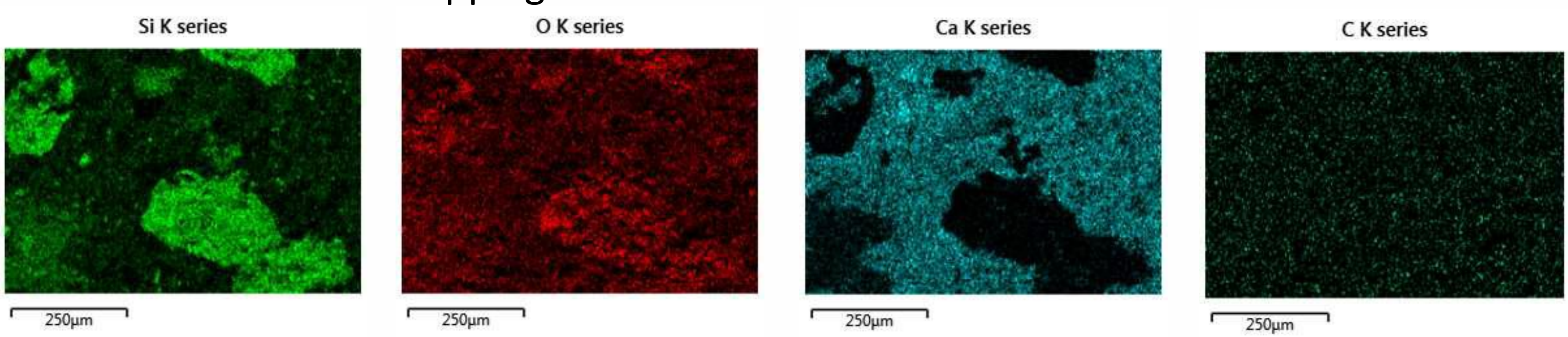


Microstructural Analysis



Individual elemental maps:

- Green - Quartz mapping
- Red - Oxides mapping
- Teal - Calcium mapping
- Blue - Carbonate mapping

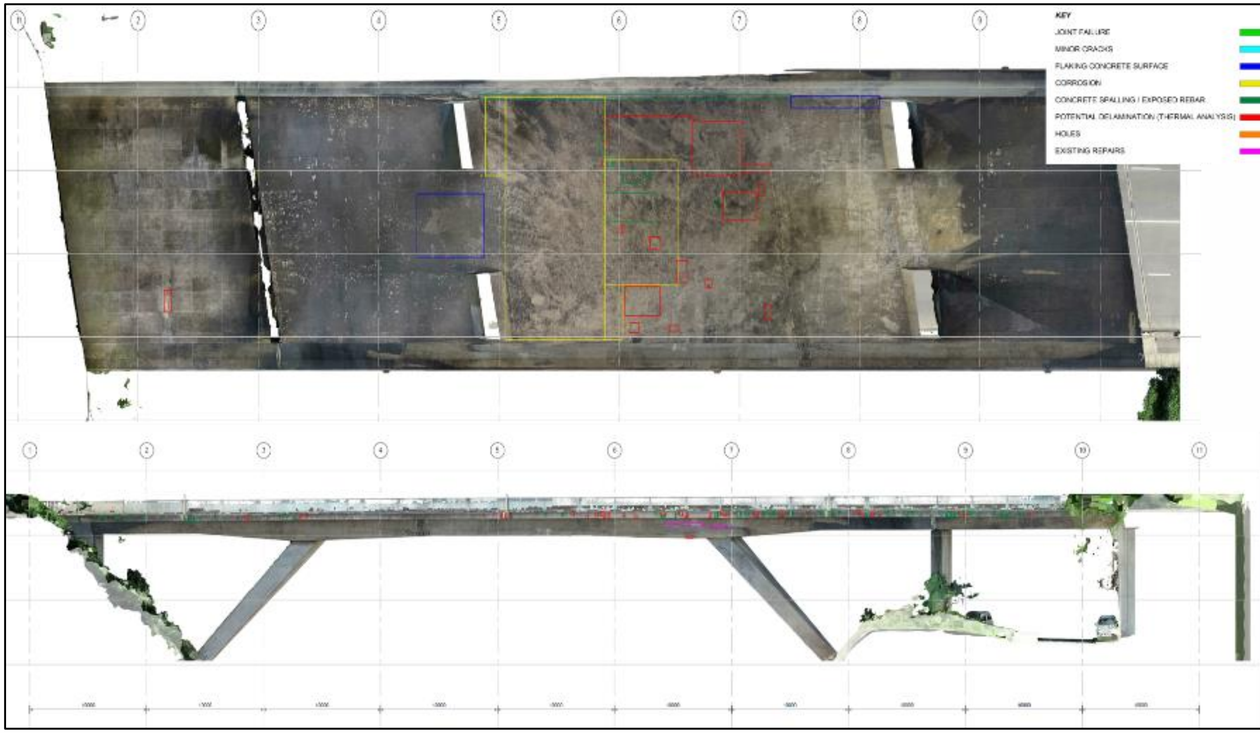


Visual Spectrum RGB (colour) and Thermal data

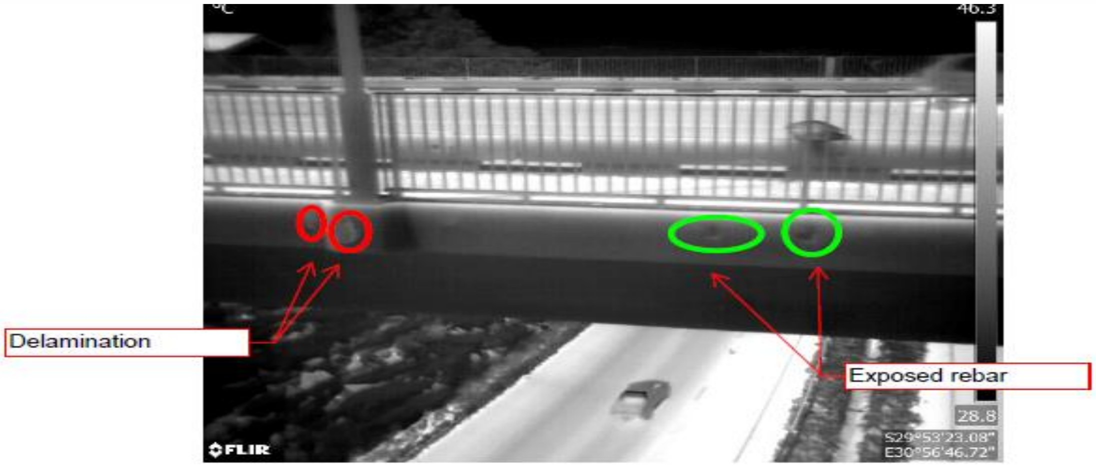
- Digital twinning
- Other defects: concrete spalling/exposed rebar, potential delamination, cracking and failure of existing repairs were identified.

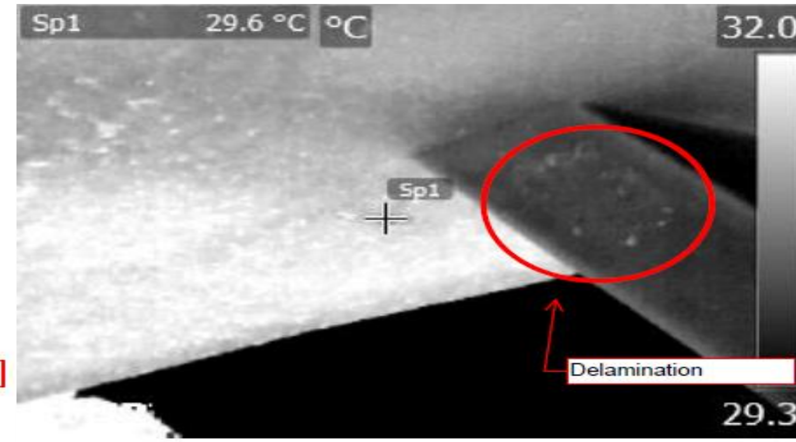
Three-dimensional (3D) Images

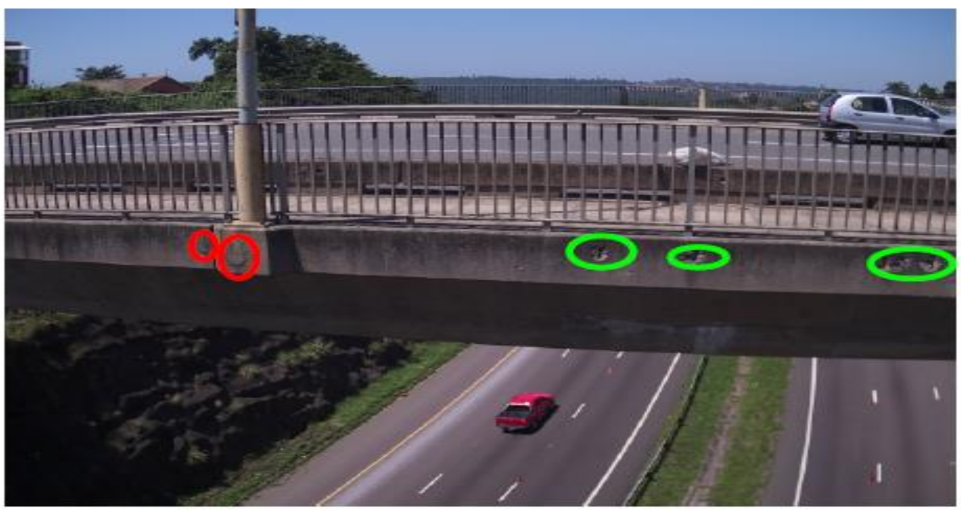
- A digital replica of the bridge is shown.
- The 3D model used to zoom into specific defects.
- Access requirements
- Appropriate repair methods to be implemented.
- Future use and reference by the client and other consultants/bridge inspectors.



Thermal Imagery Defects





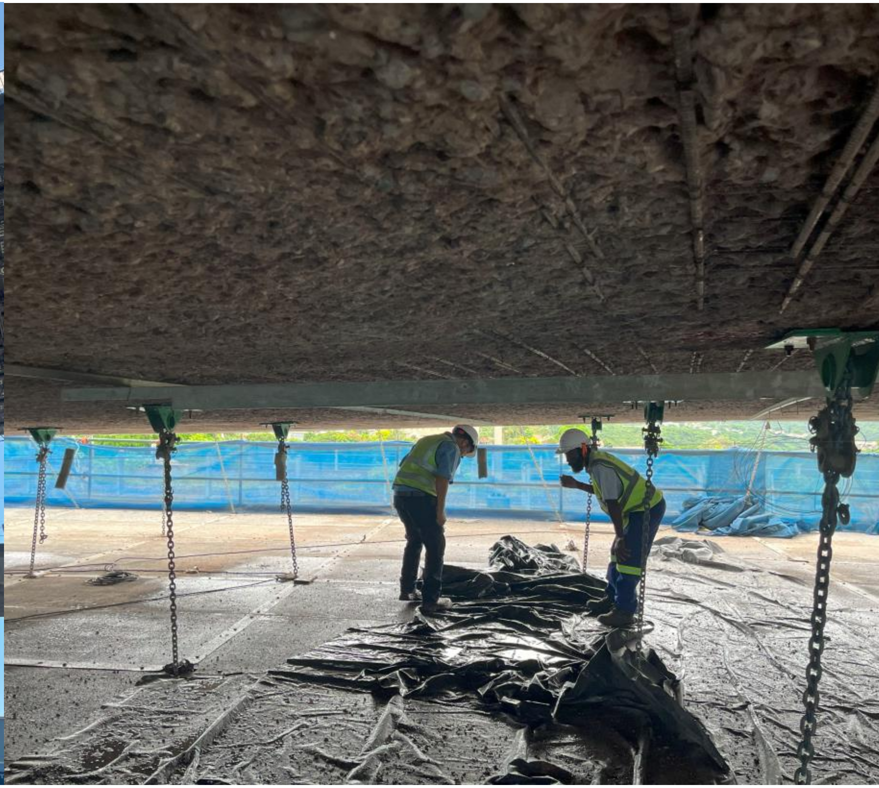


Conclusion on Design Objectives

- Repairing spalled areas is essential not only to restore the bridge's aesthetics, but more importantly, to restore its durability.
- Repairing the damaged areas ensures that the bridge's lifespan is extended, protecting it from further deterioration caused by the fire's impact.
- The fire incident and subsequent damage increases the risk of corrosion in the steel reinforcement. By addressing these compromised areas, the chances of corrosion-related deterioration are mitigated.

Access and Pre-construction Testing

- Suspended Access System
- Preconstruction Testing



Protection and Repair Objectives

EN 1504 principles for protection and repair, in terms of damage to the concrete and damage induced by reinforcement corrosion. (Fulton's Concrete Technology, 2021)

	Observation	**Cause of defects**	**Principle of remedial actions**
Defects in concrete	Cracks. Spalling. Delamination. Disintegration of the matrix.	Thermal - fire	Protection against ingress (PI). Moisture control (MC). Increasing physical resistance (PR).
Reinforcement corrosion	Uniform corrosion. Pitting corrosion. Cracking.	Carbonation of concrete.	Preserving or restoring passivity (RP). Control of anodic areas (CA).
		Corrosive contaminants: chlorides	Control of anodic areas (CA). Preserving or restoring passivity (RP).

Protection and Repair Methodology

EN 1504 principles for protection and repair, in terms of damage to the concrete and damage induced by reinforcement corrosion. (Fulton's Concrete Technology, 2021)

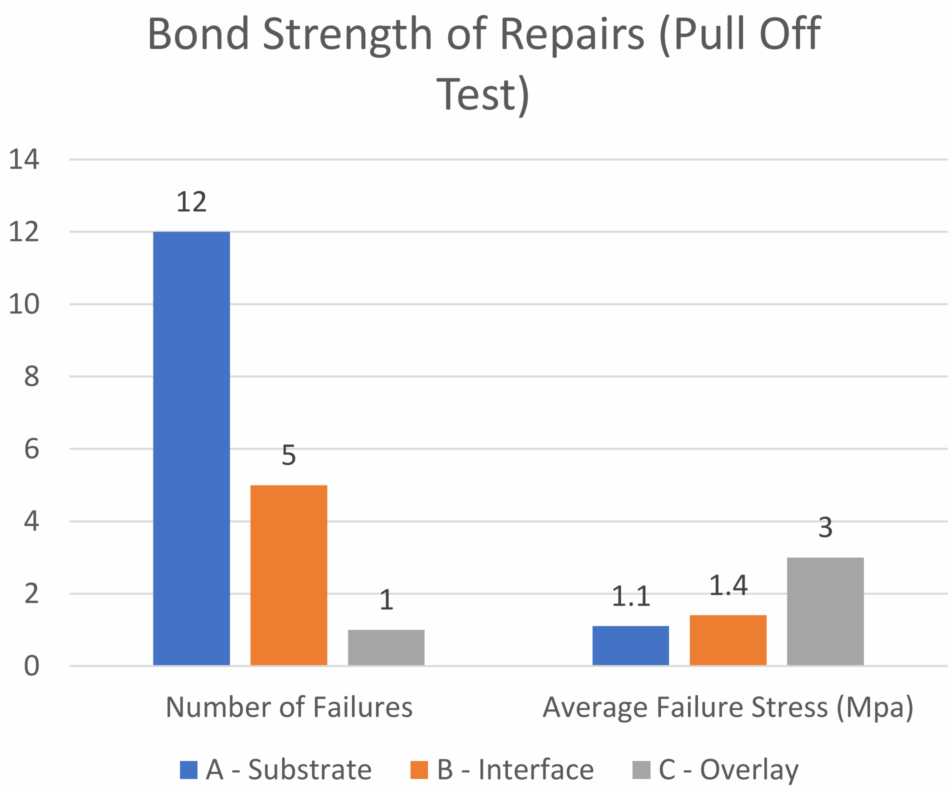
	Principle	Method
Surface Protection	*Protection against ingress (PI):* Reducing or preventing the ingress of adverse agents, e.g. water, other liquids, vapour, gas, chemicals, and biological agents.	Surface impregnation. Surface coating. Filling cracks. Applying membranes.
	Moisture control (MC): Adjusting and maintaining the moisture content in the concrete within a specified range of values.	Hydrophobic impregnation. Surface coating.
Repair	*Concrete restoration (CR):* Restoring to the originally designed shape and function.	Hand-applied mortar. Recasting with concrete. Sprayed concrete or mortar. Replacing elements.
	Preserving or restoring passivity (RP): Creating chemical conditions in which the surface of the reinforcement is maintained in, or is returned to, a passive condition.	Increasing cover with additional concrete or mortar. Replacing contaminated or carbonated concrete.
	Control of anodic areas (CA): Creating conditions in which potentially anodic areas of reinforcement are unable to participate in corrosion reaction.	Painting reinforcement with coatings containing active ingredients (e.g. zinc). Painting reinforcement with barrier coatings. Applying penetrating corrosion inhibitors to the concrete surface.

Repair and Protection Methodology

- Vertical and overhead repair methods
- Selection of appropriate materials for specific repairs
- Review of repair methodology

Repair Performance and Testing

- Sprayed concrete Class D32/40-XC4
- Compressive Strength (56,5 Mpa)
- Bond Strength



Objectives Achieved

- Repairing spalled areas to restore its durability.
- Repairing the fire damaged areas
- Protection from further deterioration caused by the fire's impact.
- Mitigation of corrosion-related deterioration


THANK YOU!