ConPaveStruc 2023

A STIFFNESS DAMAGE ASSESSMENT OF CONCRETE FROM A REINFORCED CONCRETE RAILWAY BRIDGE SUBJECT TO ALKALI SILICA REACTION (ASR) DETERIORATION IN JOHANNESBURG

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Outline

- Background – ASR
- Introduction
- Micro X-ray fluorescence (µ-XRF) spectrometry of concrete discs
- Ultrasonic pulse velocity measurements (UPV) of concrete cores
- Stiffness damage test of concrete cores
- Conclusion

Background – ASR

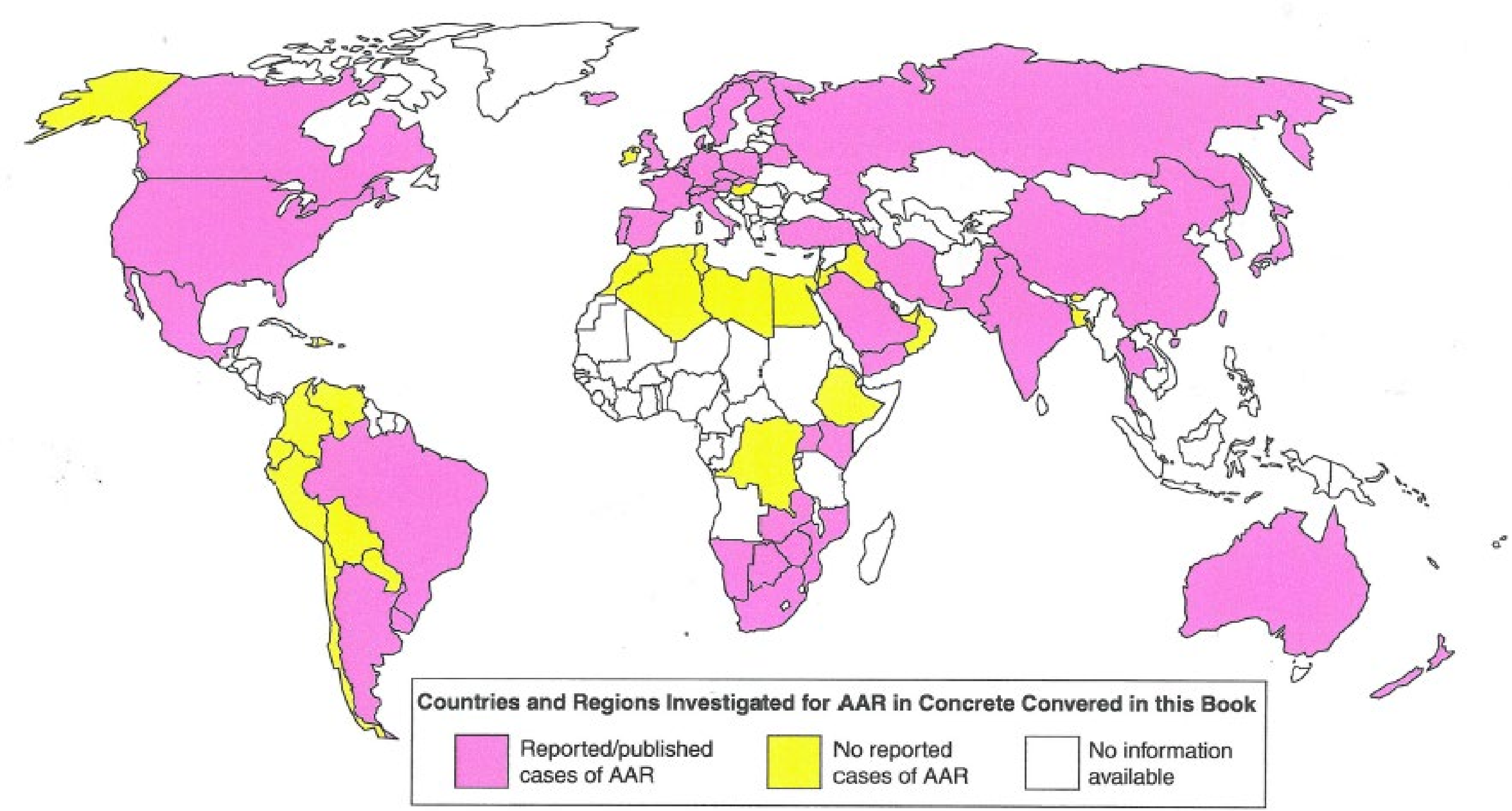


Fig. 1 : *A world map indicating areas or regions where AAR in concrete structures have been identified, investigated, reported or where avoidance specifications are in place*

Background – ASR

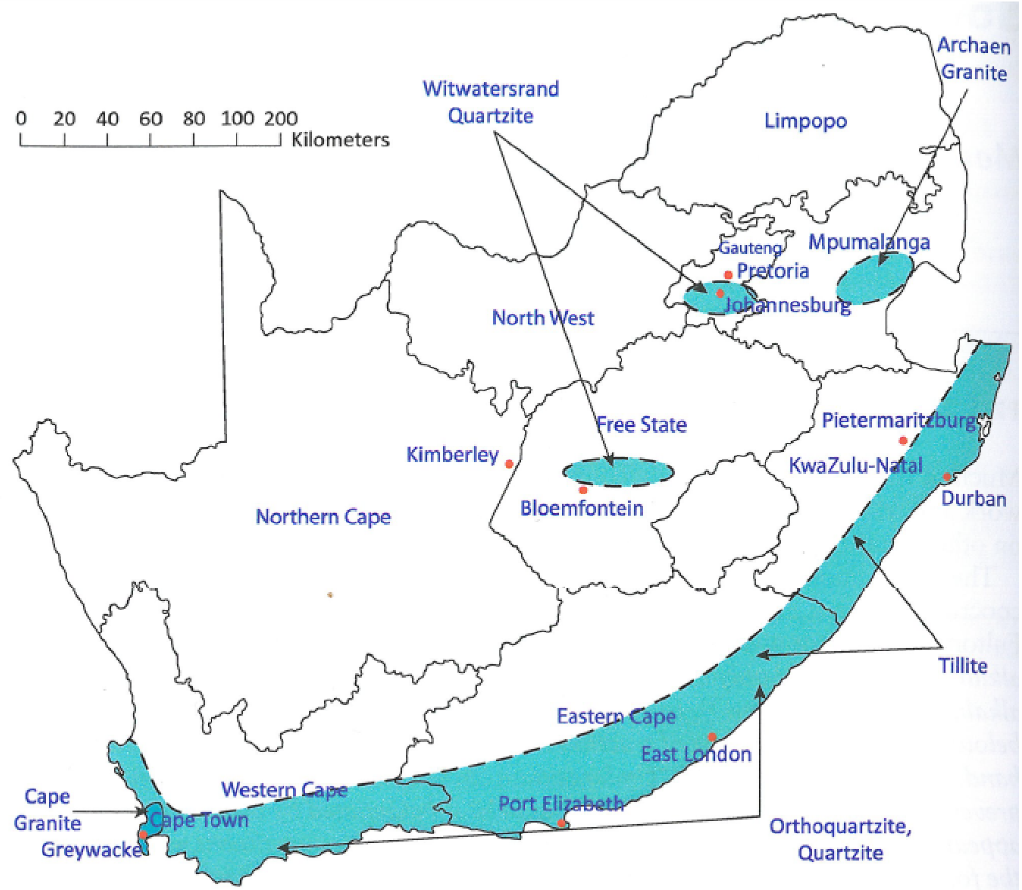


Fig. 2 : *Reactive aggregates found in various provinces in South Africa*

Introduction

PhD topic
"Estimating the Potential Residual Expansion due to Alkali Silica Reaction (ASR) in Existing Reinforced Concrete Structures"

1st phase of project
Identification of a field structure that was likely prone to ASR deterioration:

- region contains aggregates that are "reactive"
- in-service RC structure should display a degree of visual distress

2nd phase of project
Characterisation of concrete taken from various locations of the RC railway bridge prone to ASR deterioration

- Confirmation of underlying form of deterioration
- Alkali content
- Mechanical properties

Introduction

- A RC Railway bridge located in central Johannesburg which displayed signs of distress in the form of severe map-cracking, was selected as the field structure that was likely prone to ASR deterioration.

Fig. 3 *: North facing view of Railway Bridge on Treu Road and Crown Mines Spur*

Fig. 4 : *South facing view of Railway Bridge on Treu Road and Crown Mines Spur*

Introduction

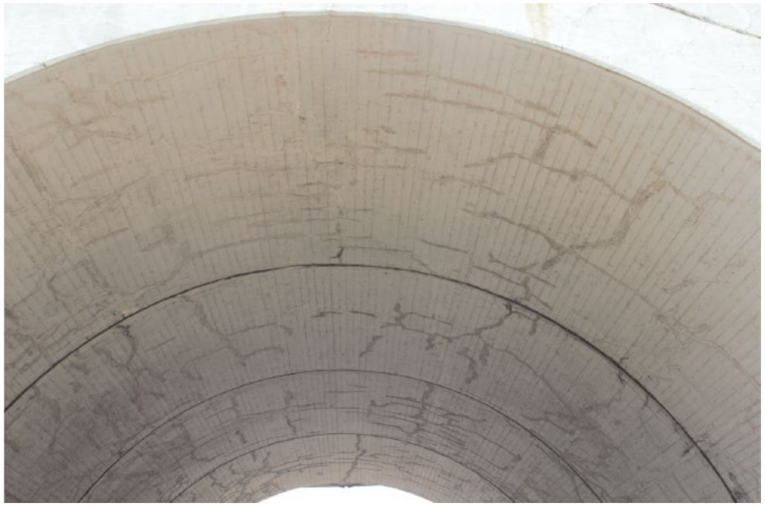
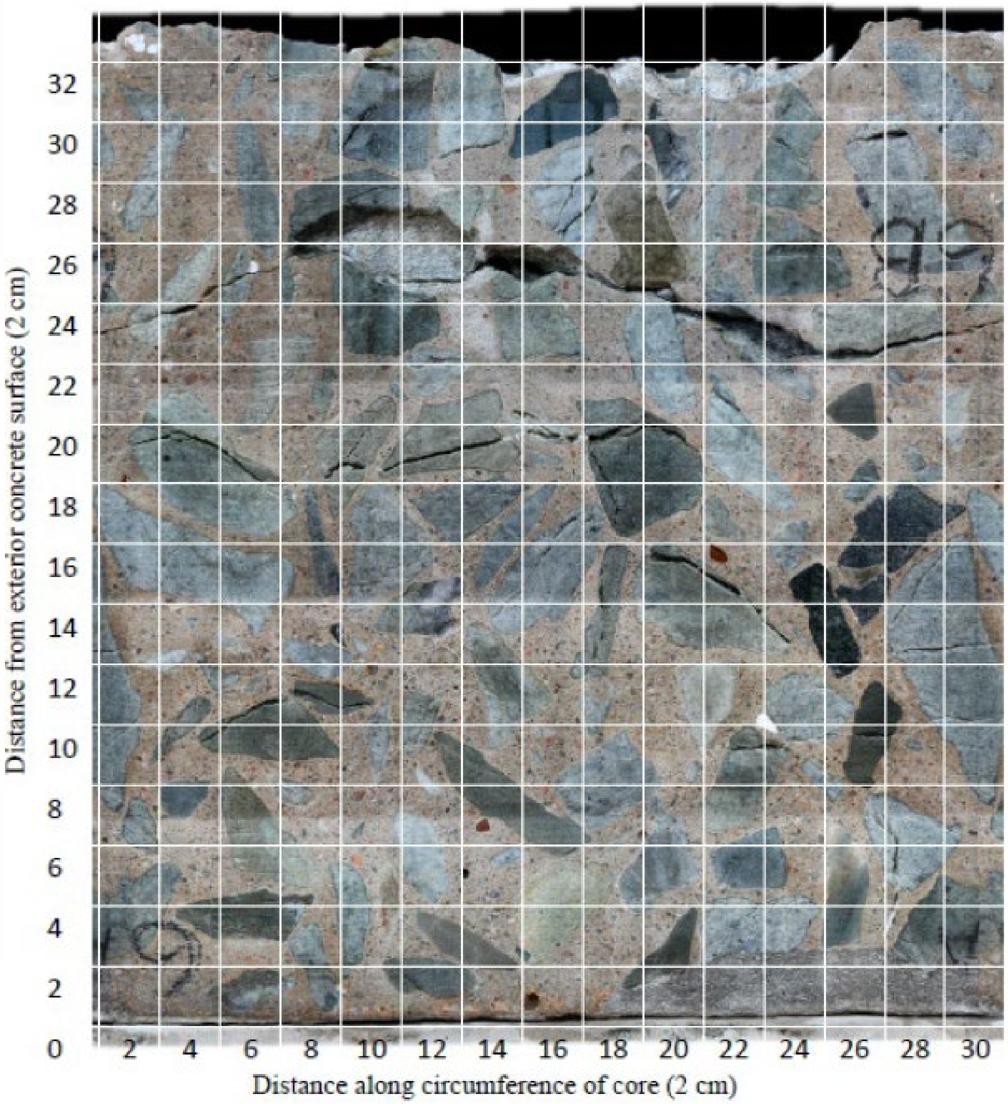


Fig. 5, 6, 7, 8 : *Evidence of map-cracking on various bridge elements*

Introduction



Petrographic Feature	Weighting factor
Crack in aggregate	0.25
Crack in matrix	0.5
Reaction rim	0.5
Crack in aggregate with ASR gel	2
ASR gel in air void	2
Debonded aggregate	3
Corroded aggregate	3
Crack in matrix with ASR gel	4

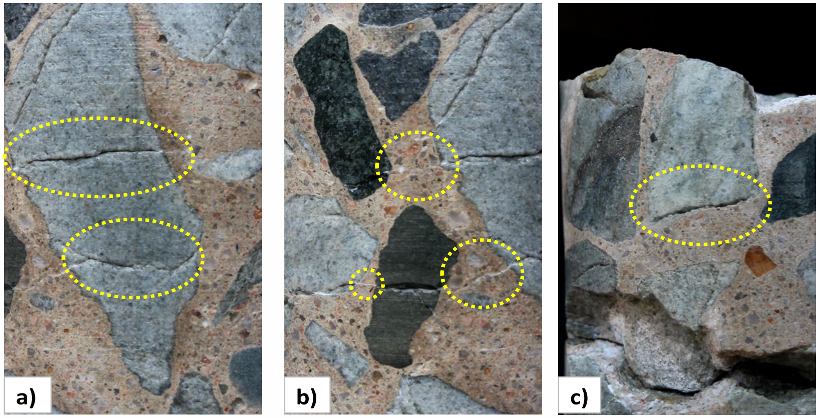


Fig. 10: *Petrographic features observed in as-received cores*

Fig. 9: *2D global image of core C6 cylindrical surface (note the image has been scaled down ,the actual grid size is 2cm^2)*

Micro X-ray Fluorescence (μ-XRF)

Fig 11. *Bruker μ-XRF instrument at Mintek, South Africa*

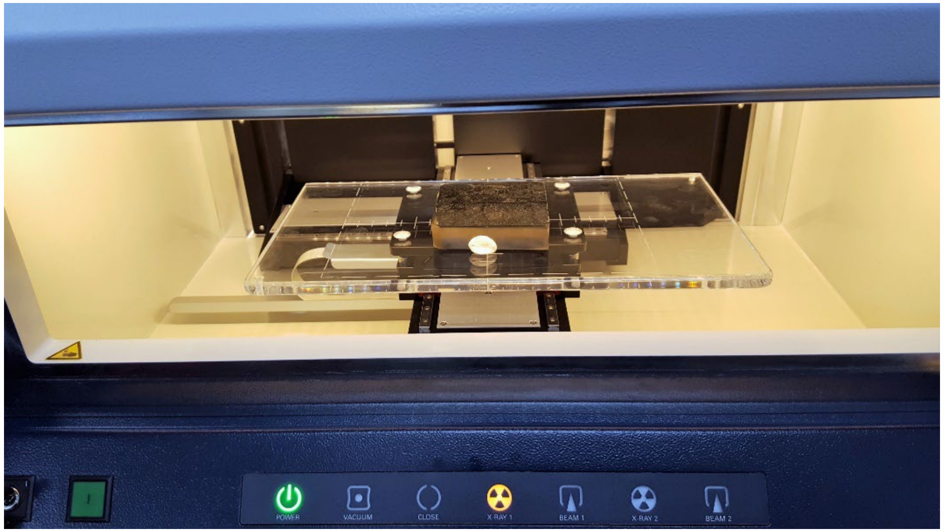


Fig 12. *μ-XRF interior showing the sample stage/holder*

Micro X-ray Fluorescence Spectrometry of concrete discs

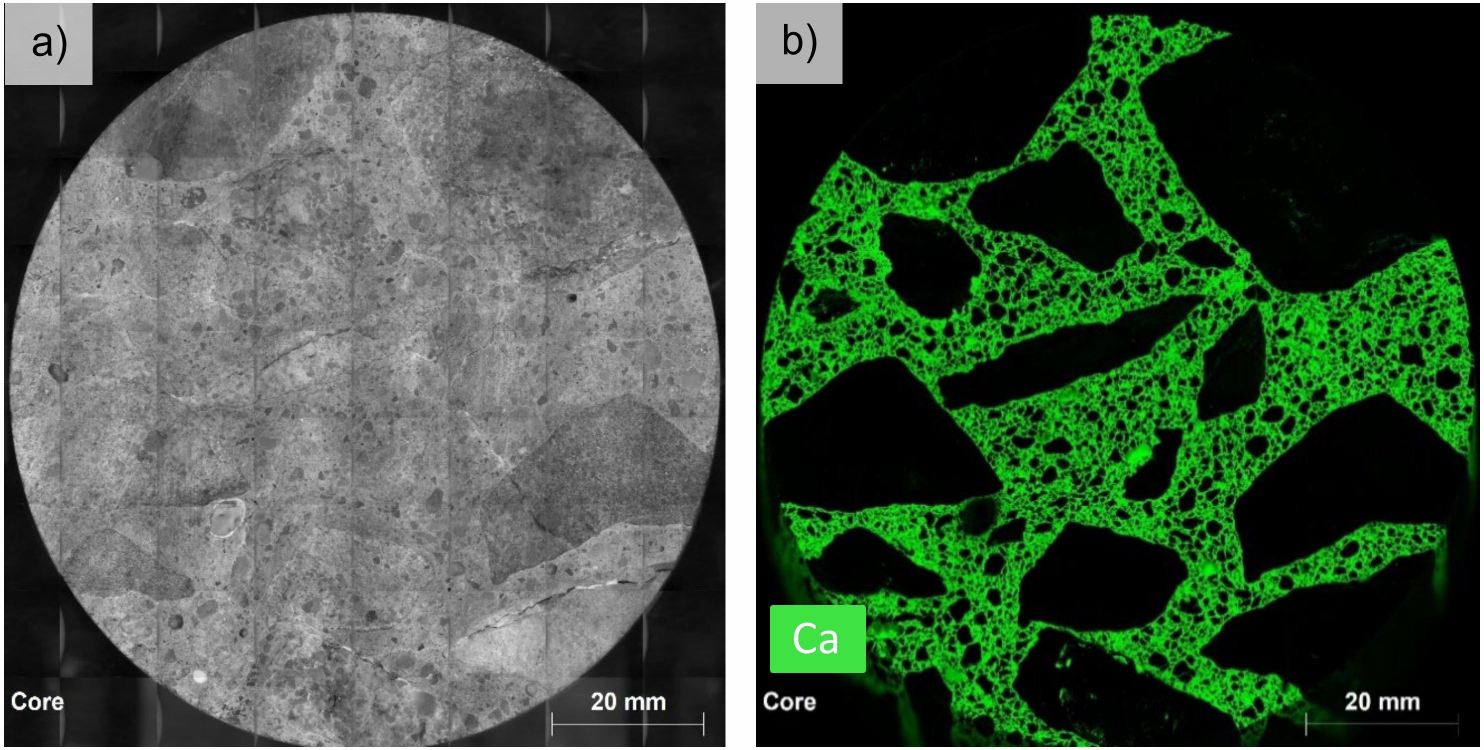
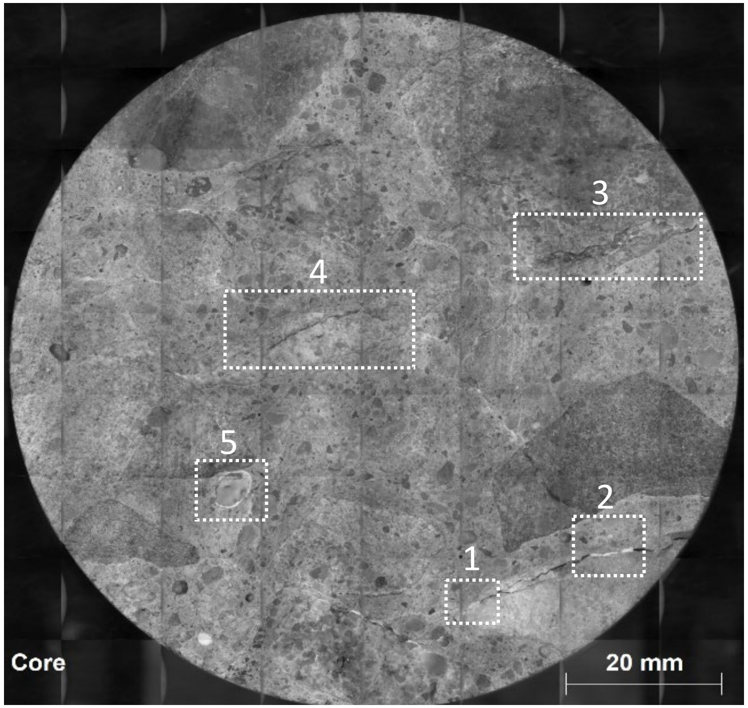


Fig. 13a: *Reference concrete disc.*
Fig. 13b: *Elemental map showing presence of calcium on the surface of concrete disc*

Micro X-ray Fluorescence Spectrometry of concrete discs



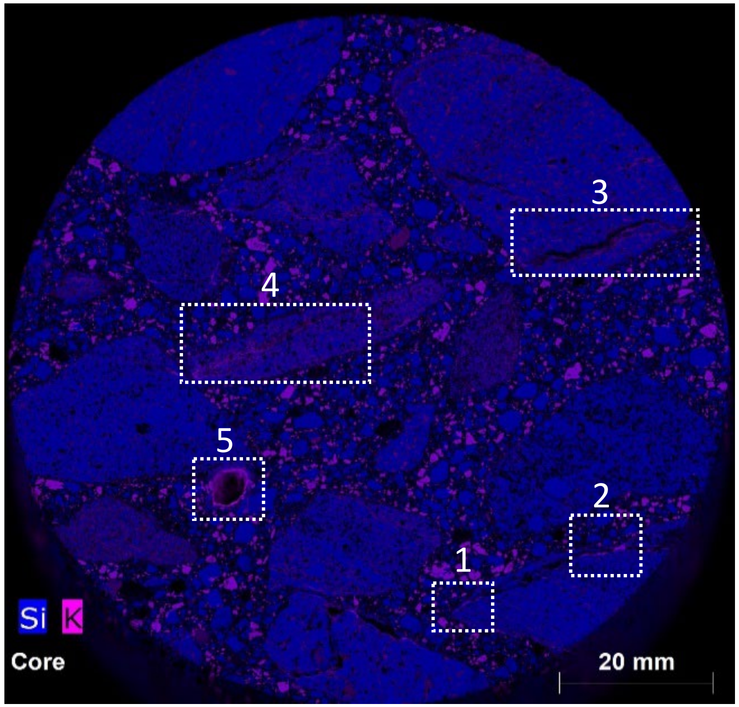


Fig. 14a: *Reference concrete disc.*
Fig. 14b: *Elemental map showing presence of silica and potassium on the surface of concrete disc*

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Micro X-ray Fluorescence Spectrometry of concrete discs

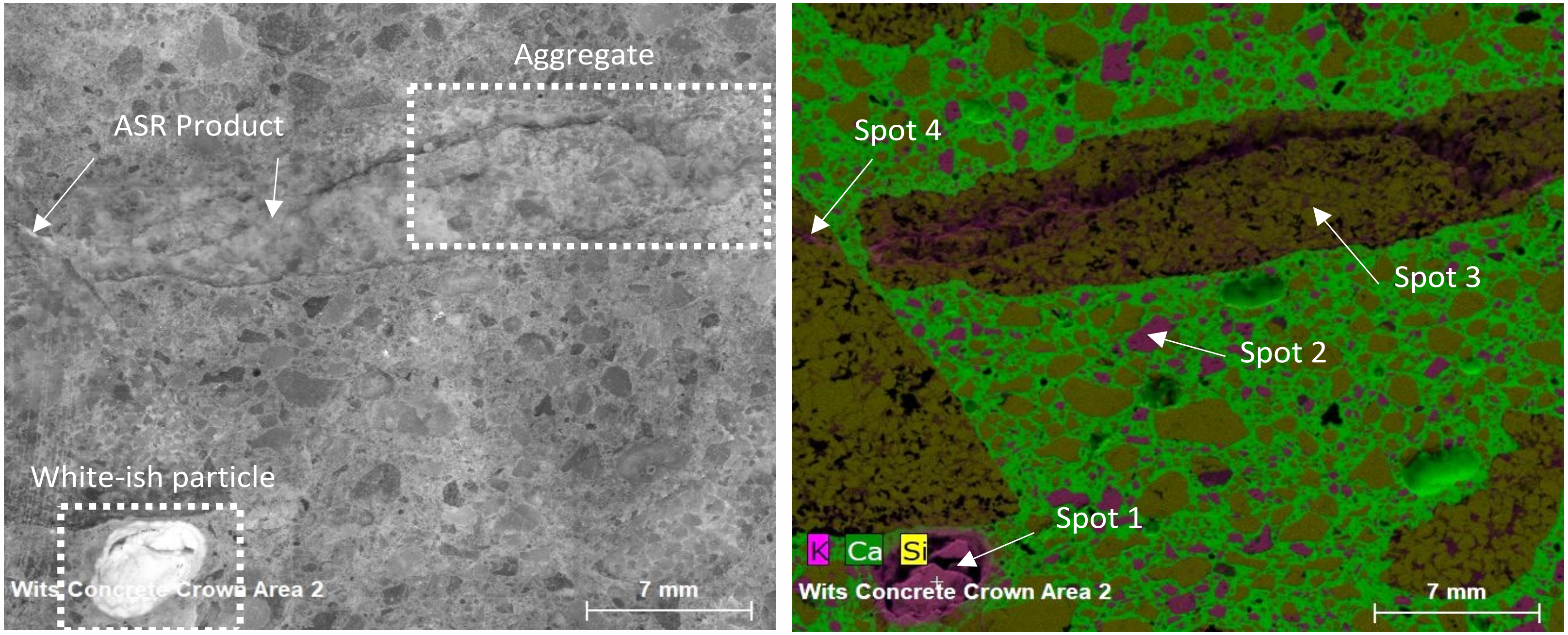

Fig. 15a: *Reference concrete disc outlining ASR product, aggregates and whitis-particle*
Fig. 15b: *Elemental map showing presence of potassium, calcium and silica on four spot areas the surface of concrete disc*

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Micro X-ray Fluorescence Spectrometry of concrete discs

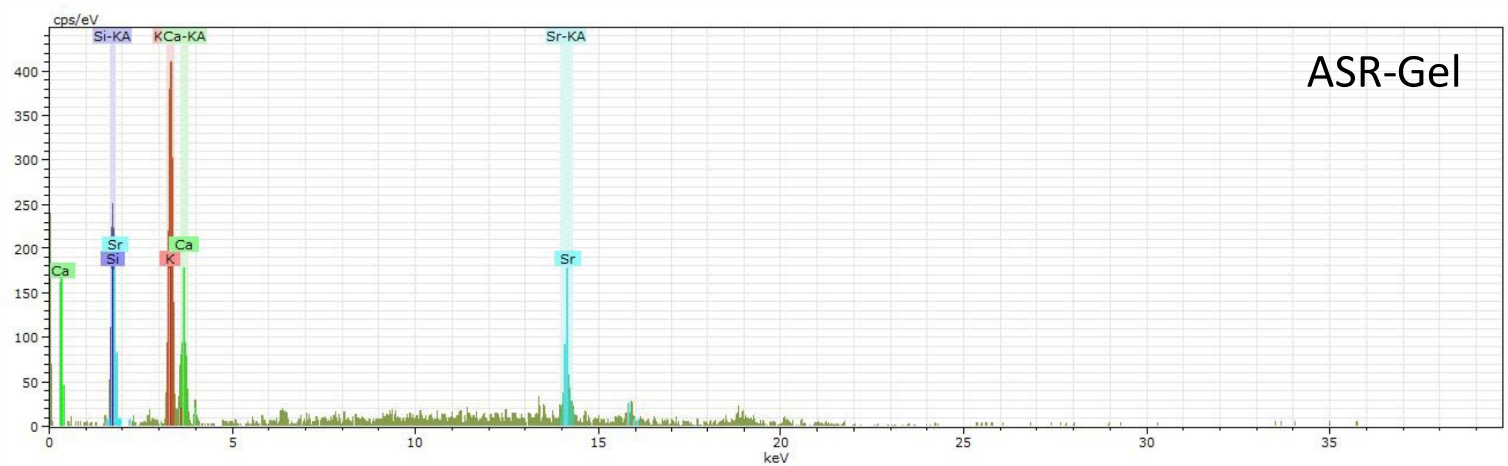

***Fig. 16:** Spectrographic analysis of phases identified in Spot 1(Cavity Material)*

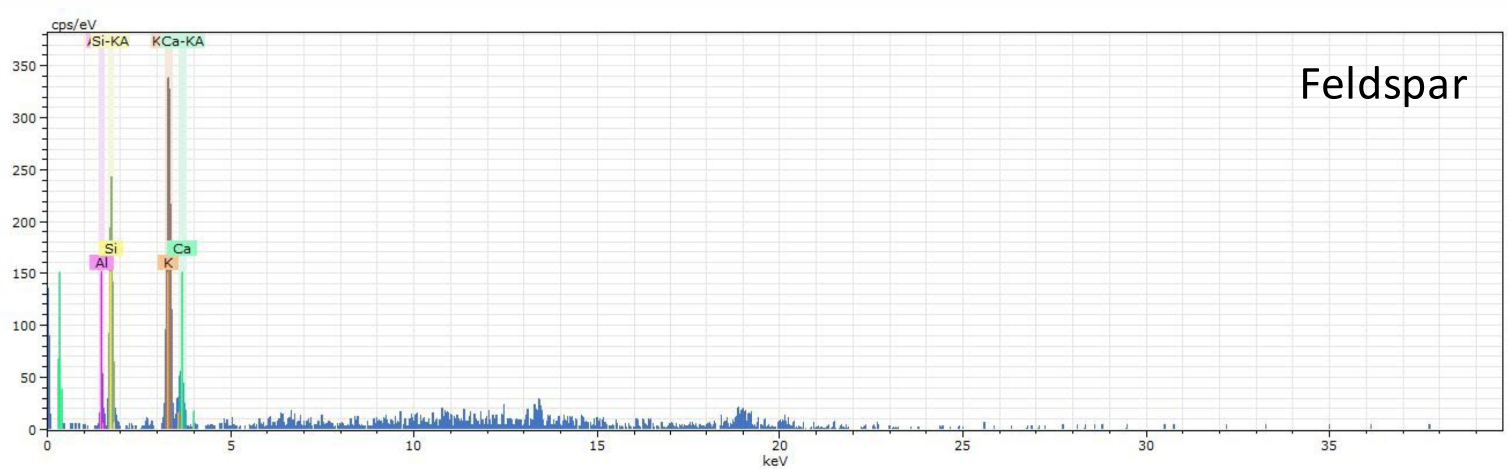

***Fig. 17:** Spectrographic analysis of phases identified in Spot 2 (K-Rich Aggregate)*

Ultrasonic pulse velocity measurements (UPV) of concrete cores

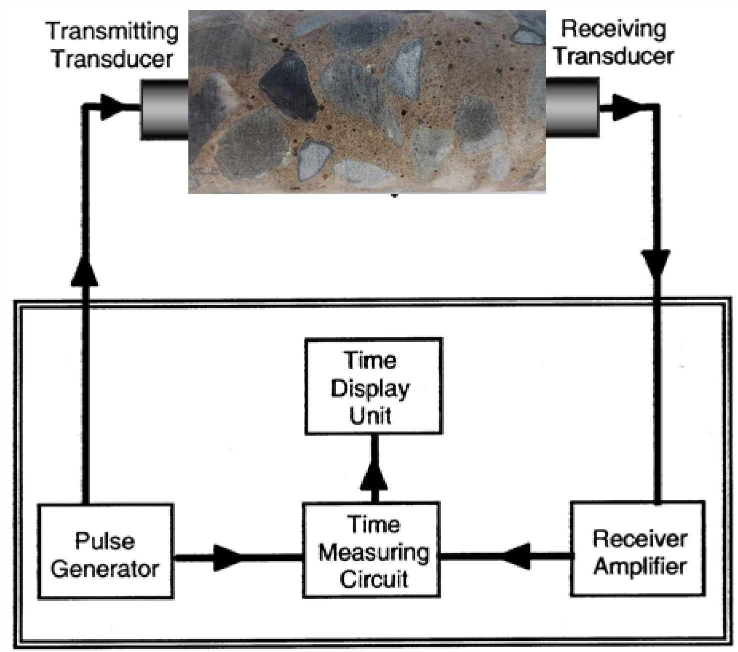

Fig.18 *Ultrasonic Pulse Velocity: Test set-up according to ASTM C597*

$$V = L/T$$

Eq 1: *Formula to determine pulse velocity*

$$V = \sqrt{\frac{E\,(1-\mu)}{\rho\,(1+\mu)(1-2\,\mu)}}$$

Eq 2: *Formula relating pulse velocity to dynamic modulus of elasticity, density and dynamic Poisson ratio*

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Ultrasonic pulse velocity measurements (UPV) of concrete cores

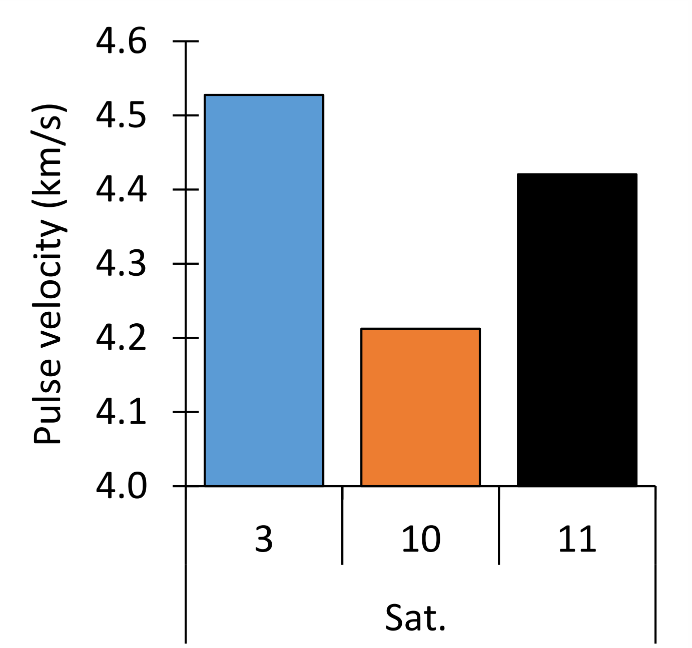


***Fig.19** Pulse velocity (Km/sec) measurements for specimens taken from various location of RC railway bridge*

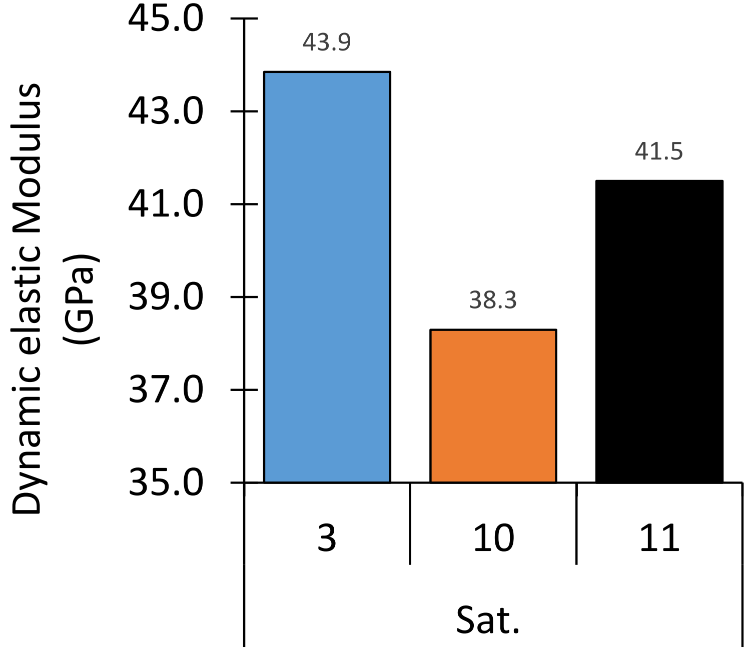


***Fig.20:** Dynamic elastic modulus based on pulse velocity results*

Stiffness damage test (SDT) of concrete cores

- Mechanical and cyclic test procedure, five compression cycles,

Using percentage (40%) of the ultimate capacity (compressive strength) of the concrete

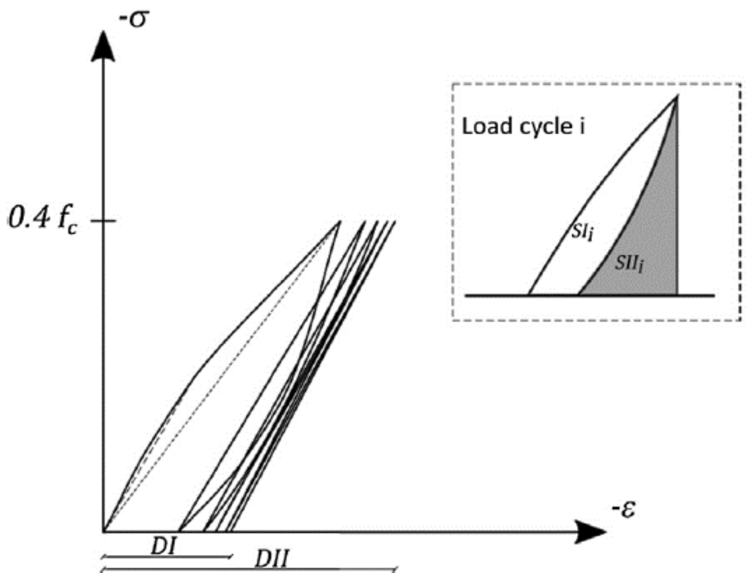
  - The modulus of elasticity,
  - dissipated energy (hysteresis area),
  - the non-linearity index (NLI; the ratio of secant modulus at half of the maximum load and the secant modulus at the peak load)

- Stiffness Damage Index (SDI)

the ratio of dissipated energy to total energy, i.e., SI/(SI + SII)

- Plastic Deformation Index (PDI)

plastic deformation to total deformation in the system, i.e., DI/(DI + DII)



Stiffness damage test (SDT) of concrete cores

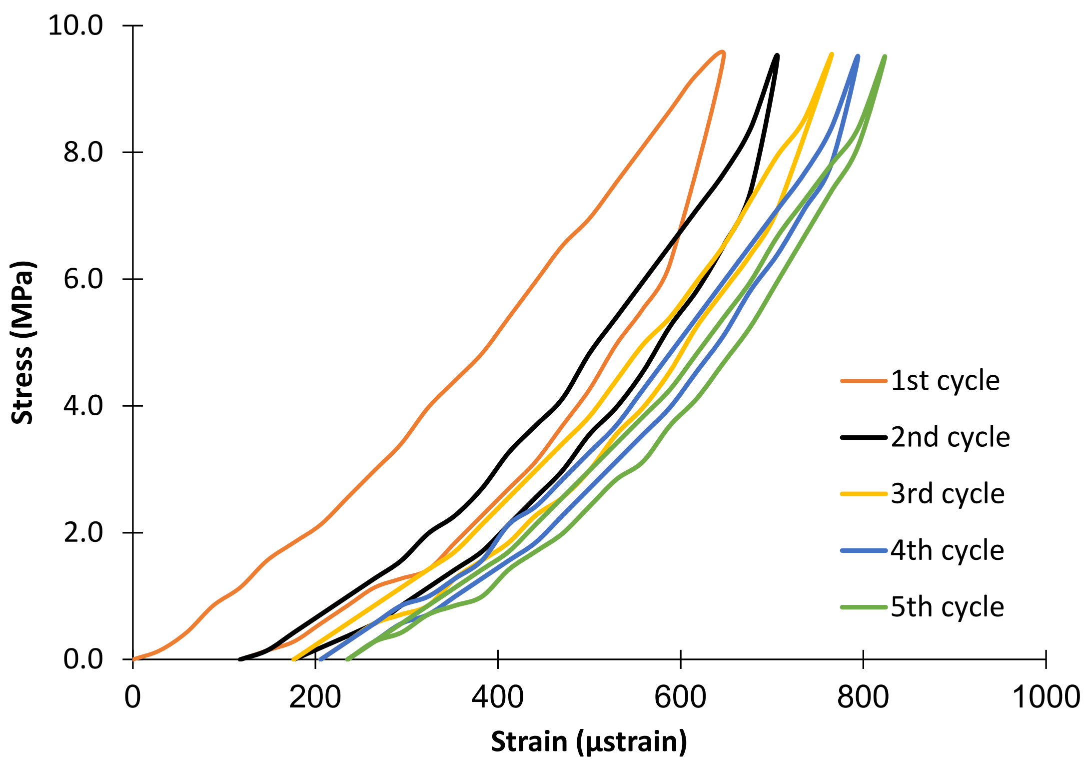
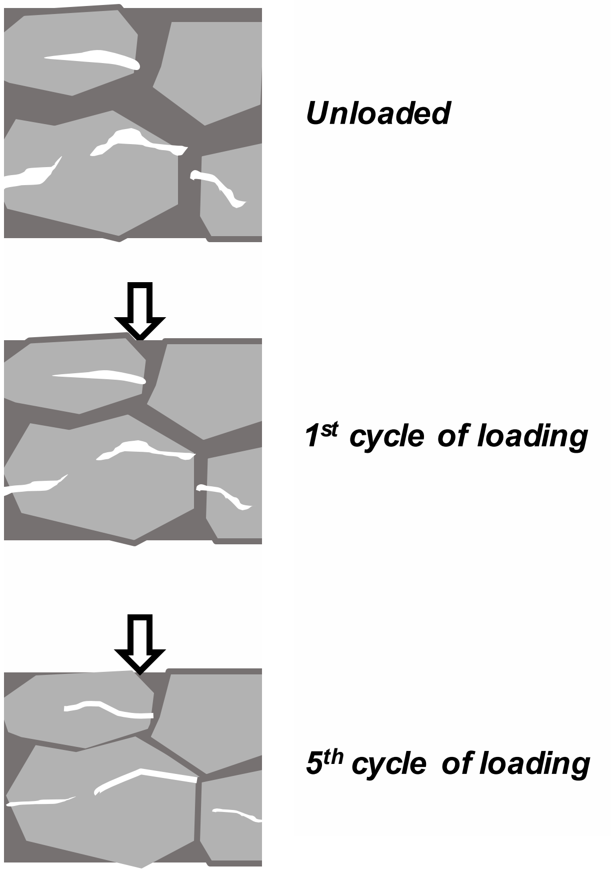


Fig. 21: Typical stress–strain behavior curves obtained for test specimens 3



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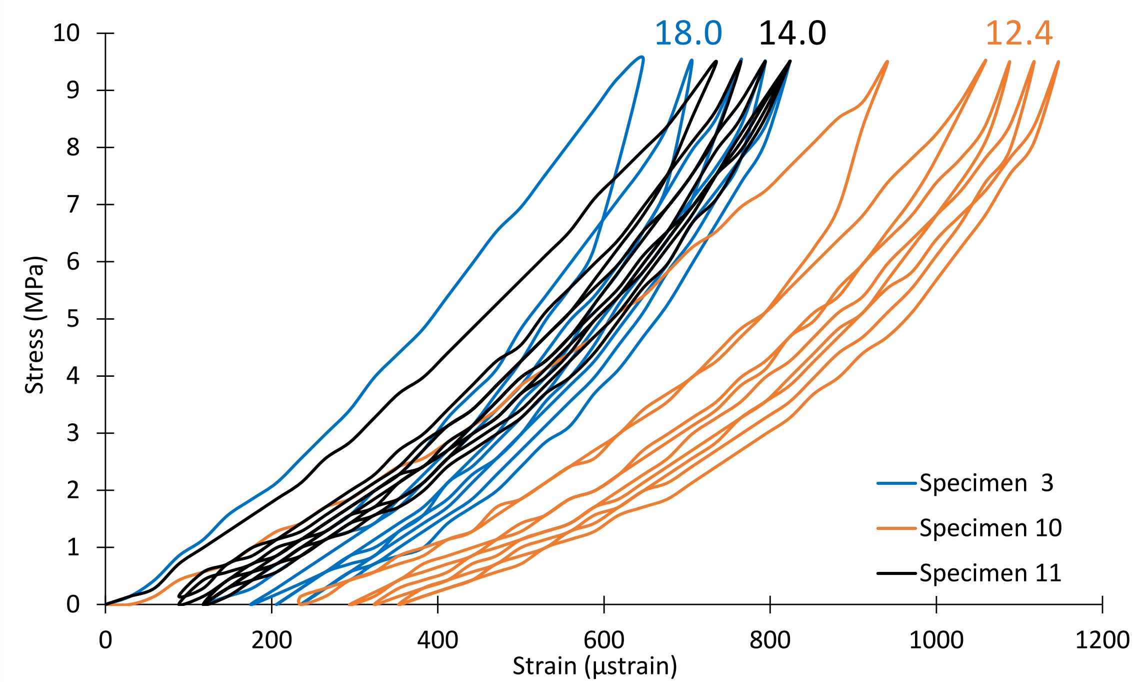
Stiffness damage test (SDT) of concrete cores



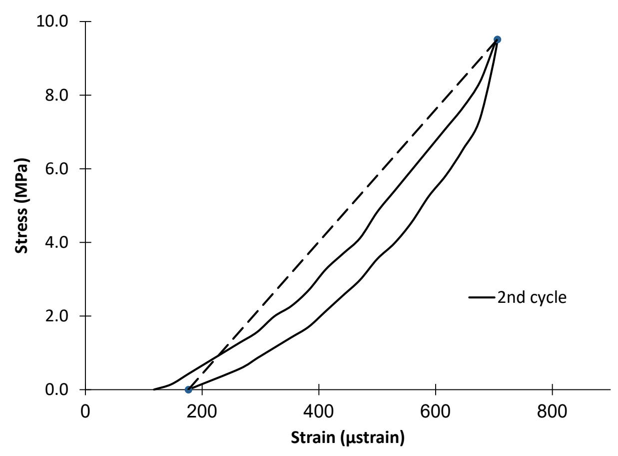


Fig. 22: *Typical stress–strain behavior curves obtained for test specimens taken from various location of RC railway bridge*

Conclusion

- uXRF-spectrometry is a useful technique to identify the elemental distribution in concrete.
- In particular the presence potassium, which assists in the identification and characterisation of ASR gel (not visible to naked-eye)
- Ultrasonic pulse velocity measurements (UPV) and stiffness damage test (SDT) are both NDT techniques used to determine the stiffness of concrete, with respect to elastic modulus of concrete.

Specimen	UPV (GPa)	Stiffness damage (GPa)
3	43.9	18.0
10	38.3	12.4
11	41.5	14.0