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An intelligent approach for predicting the performance of repair concrete in a bridge in Northern Ireland from real-time sensor data

Harshita Garg

Sreejith Nanukuttan
Queen's University Belfast

Anthony G Cohn
University of Leeds

Muhammed Basheer
University of Leeds

ABERCORN BRIDGE

- Built in 1932 in Newtownstewart, NI
- Hennebique system of RC structure
- Overall the structure was in good condition, except few critical areas

- Localised deterioration
- settlement of deck slab and cracking
- Reduced the strength of the bridge

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- Major patches filled by – shrinkage-reduced flowable concrete.
- Waterproofing – deck surface
- Breathable coating – soffit area

- Installed **Septopods** to monitor the repaired concrete;
- Check whether repaired concrete would protect the steel reinforcement from corrosion

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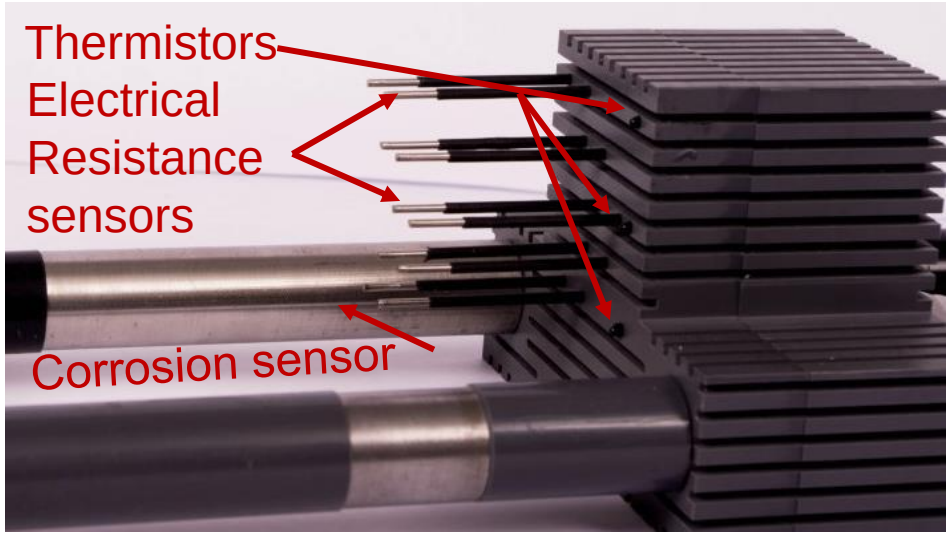
REVIEW OF SENSORS

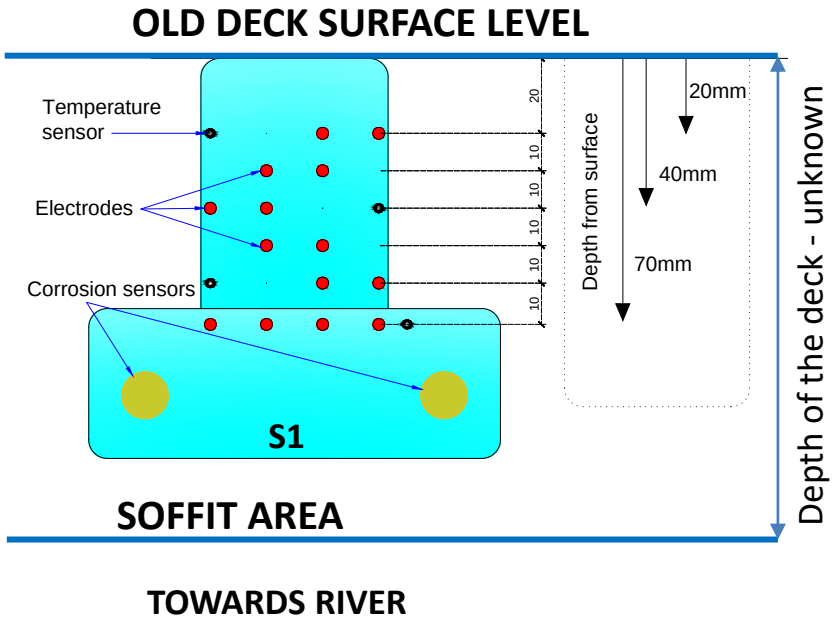
Septopod – a combination of corrosion sensors, resistance sensors and thermistors

Sensor 1 – 20 mm from deck surface near expansion joint

Sensor 2 – 20 mm from deck surface

REVIEW OF SENSORS

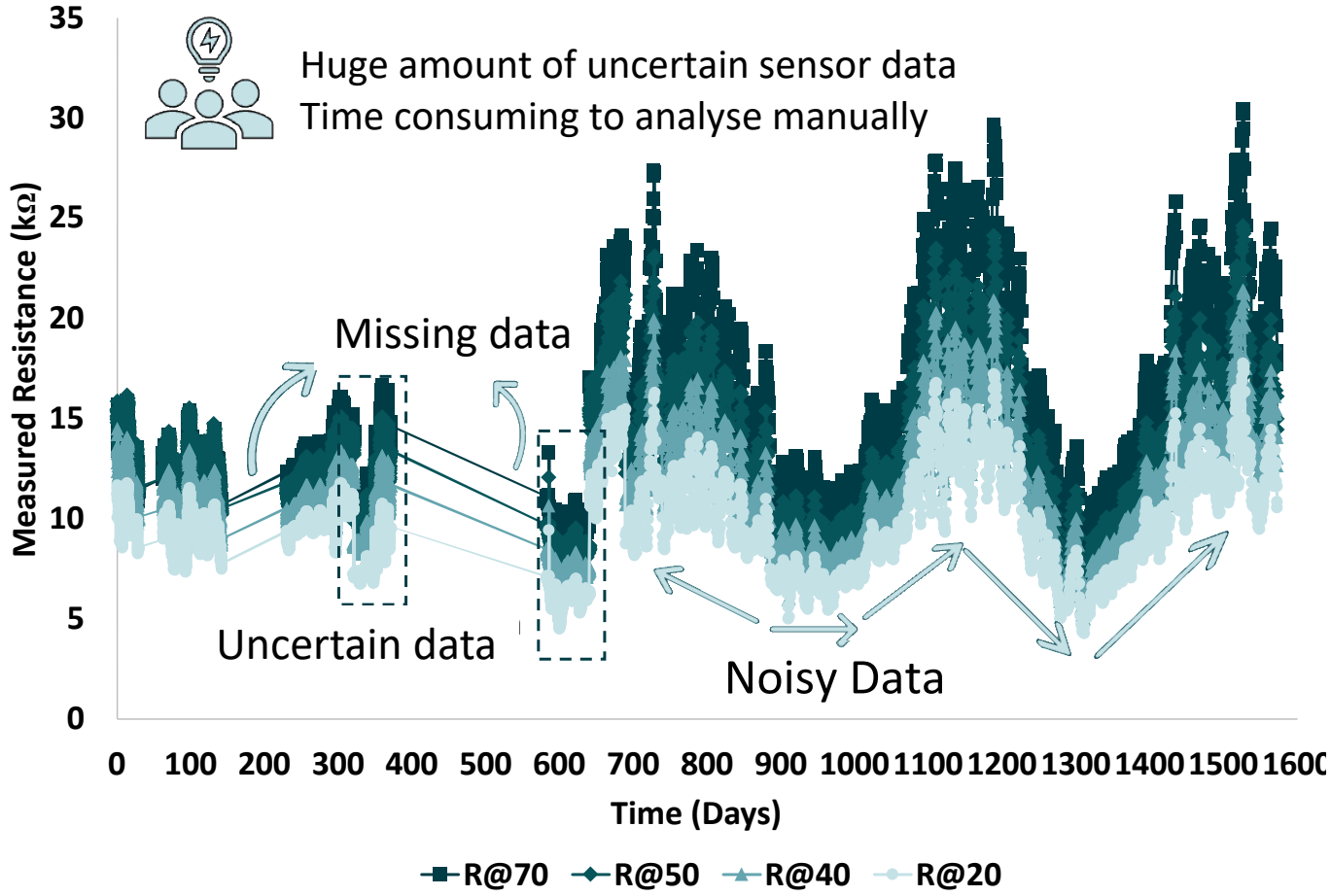




- Oriented to capture changes in electrical resistivity and temperature near the expansion joint on the deck surface.
- Data was recorded for 4 years 2 months.
- **Frequency** - Every 2 hours for 20 months and twice a day for the remaining period.

RAW DATA FROM THE SENSOR

Issues with the current practice of collecting massive uncertain data



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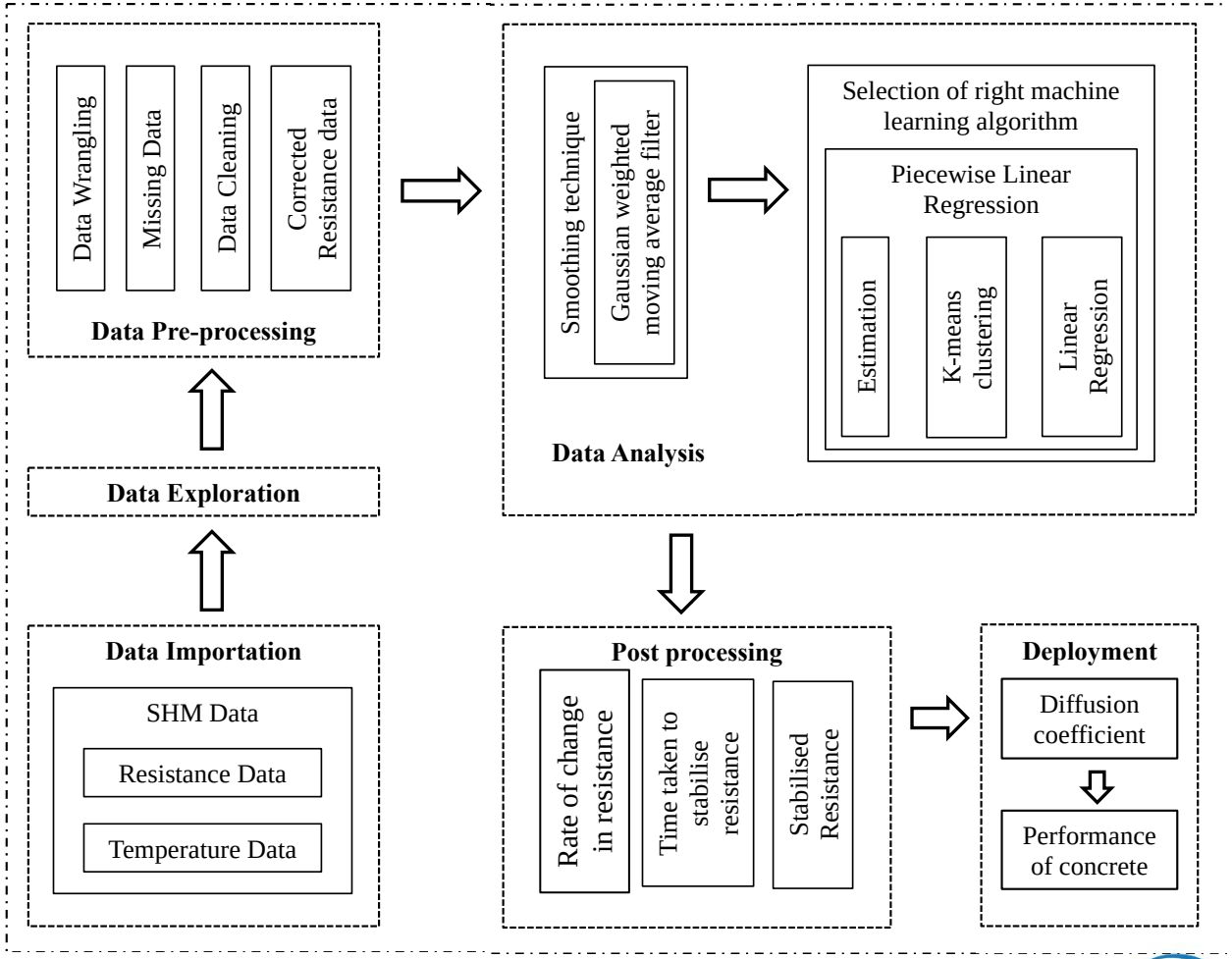
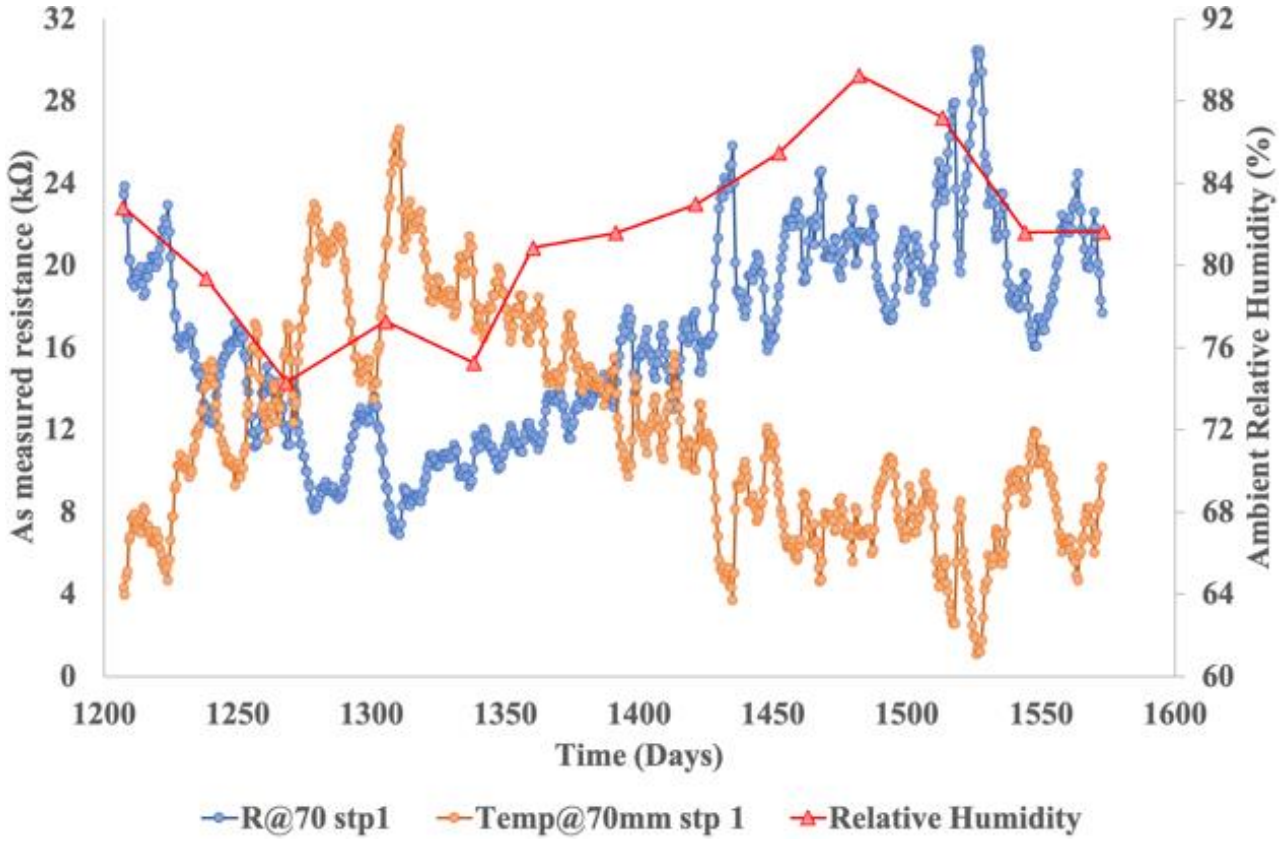
AUTOMATED AI-BASED SHM APPROACH

An **automated SHM methodology is applied to SHM data obtained from electrical resistance sensors** and thereby to calculate the diffusion coefficient for assessing the performance of the repaired concrete in service.



CORRECTION OF RESISTANCE DATA FOR TEMPERATURE

- Huge cyclic variation in resistance for both sensors.
- Resistance ∝ 1 / temperature
- Arrhenius relationship to reduce the influence of temperature on electrical resistance and standardised to 25°C.
- Huge fluctuations in as-measured resistance are reduced in standardised resistance.



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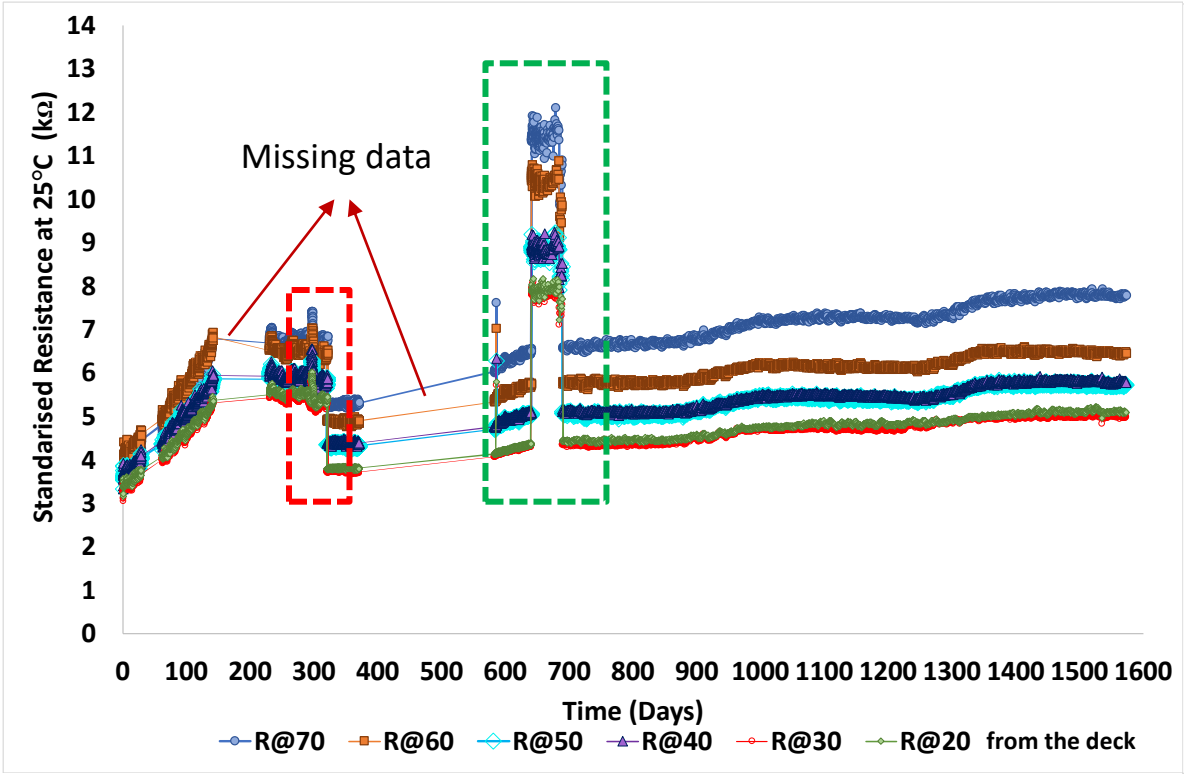
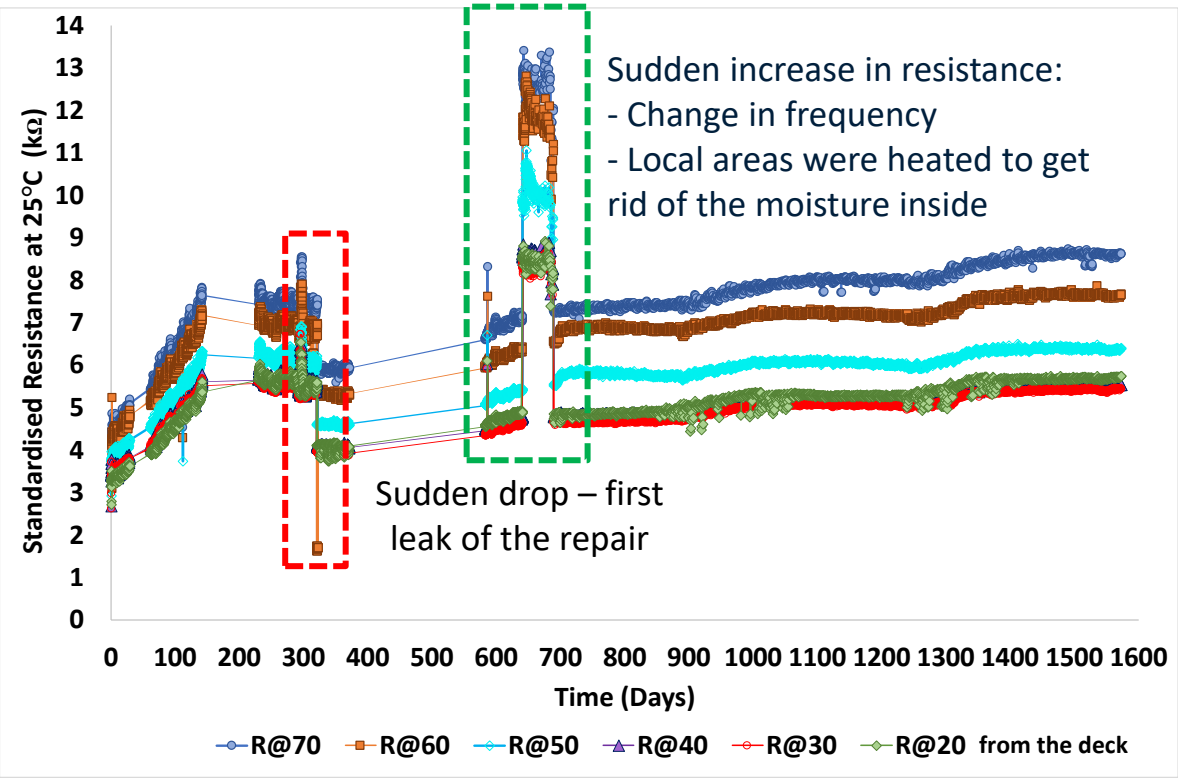
STANDARDISED RESISTANCE DATA

SEPTOPOD 1



SEPTOPOD 3



To assess the performance of repaired concrete

Discuss four parameters:

- Initial rate of increase in resistance,
- Value of stable resistance,
- Time taken to reach a stabilised resistance value,
- Value of Diffusion coefficient.

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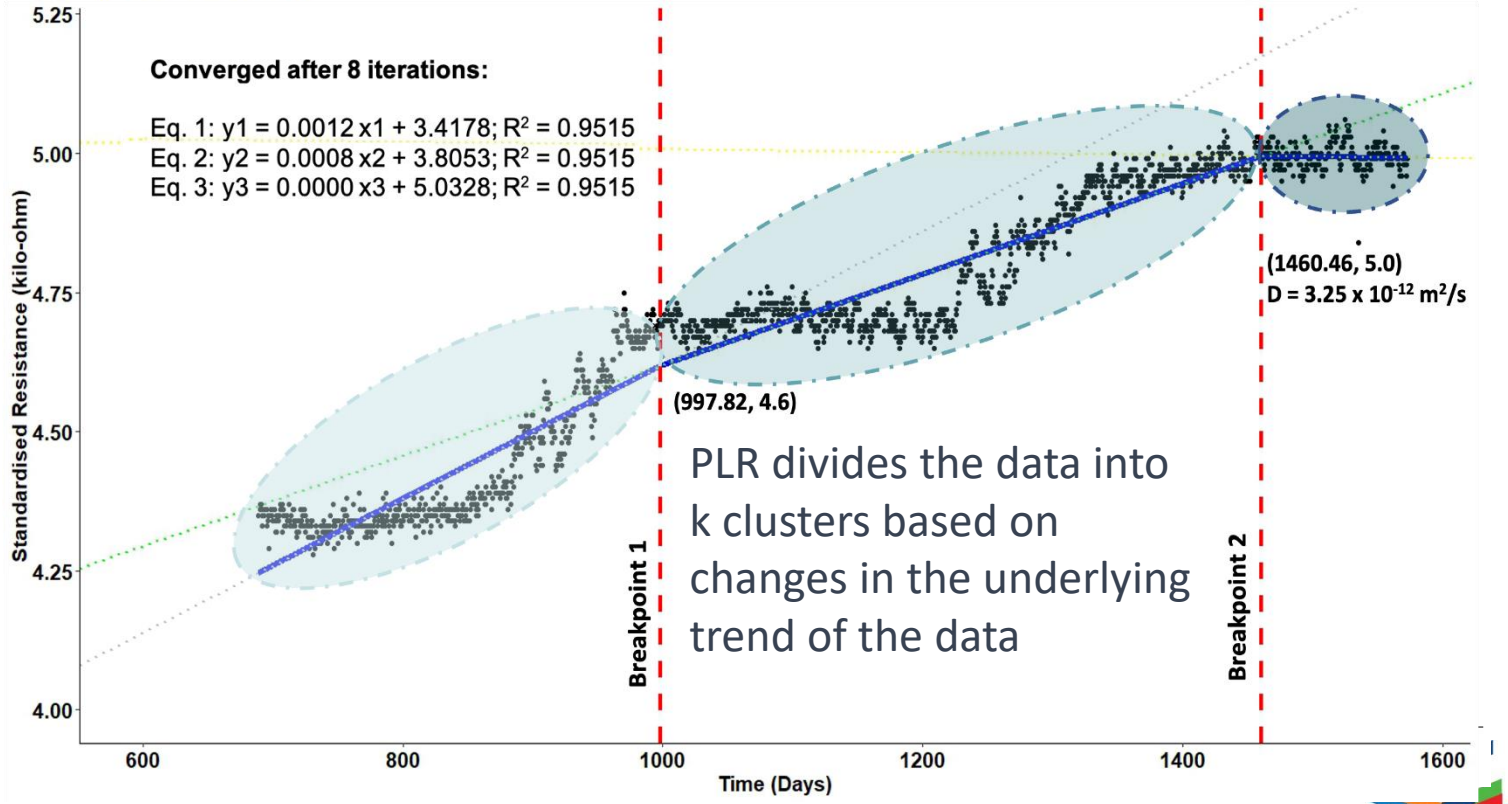
AUTOMATED CLUSTERING-BASED SEGMENTED REGRESSION

Machine learning

- Select variables to be used for analysis
- Optimal number of clusters - Elbow Method, Silhouette analysis
- Clustering - Group the data into k clusters
- Perform piecewise linear Regression
- Combine the predictions from all the models to obtain overall relationship



PLR divides the data into k clusters based on changes in the underlying trend of the data

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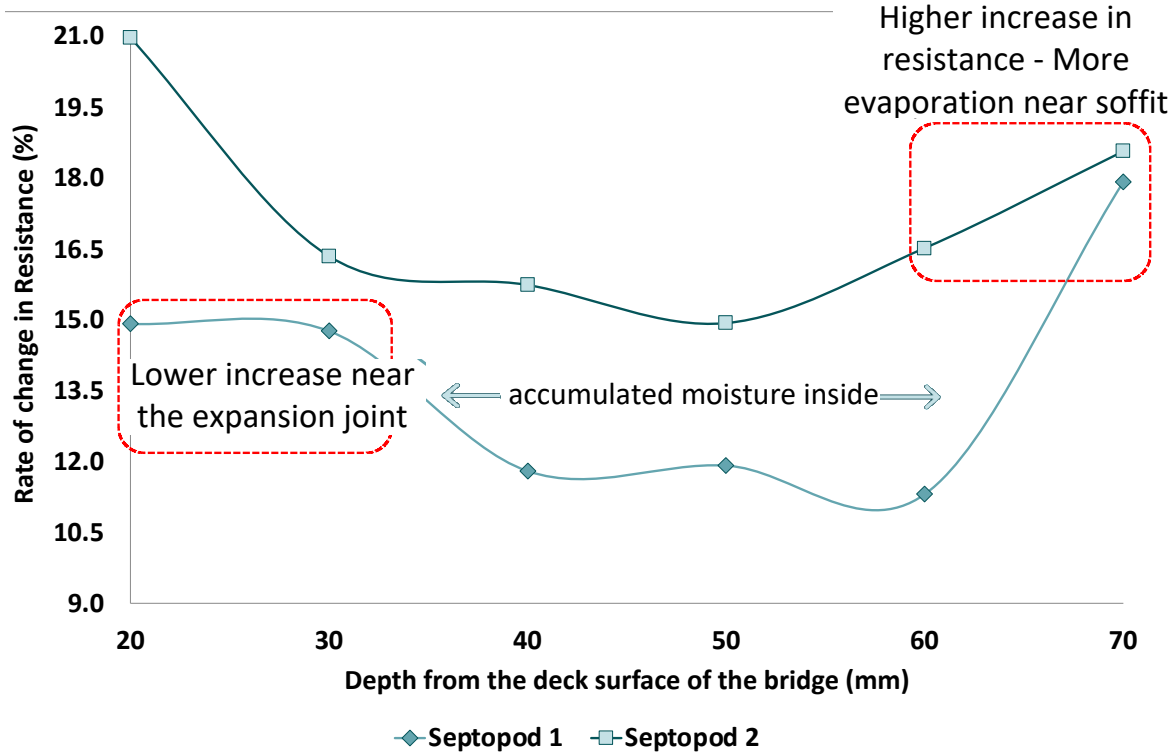
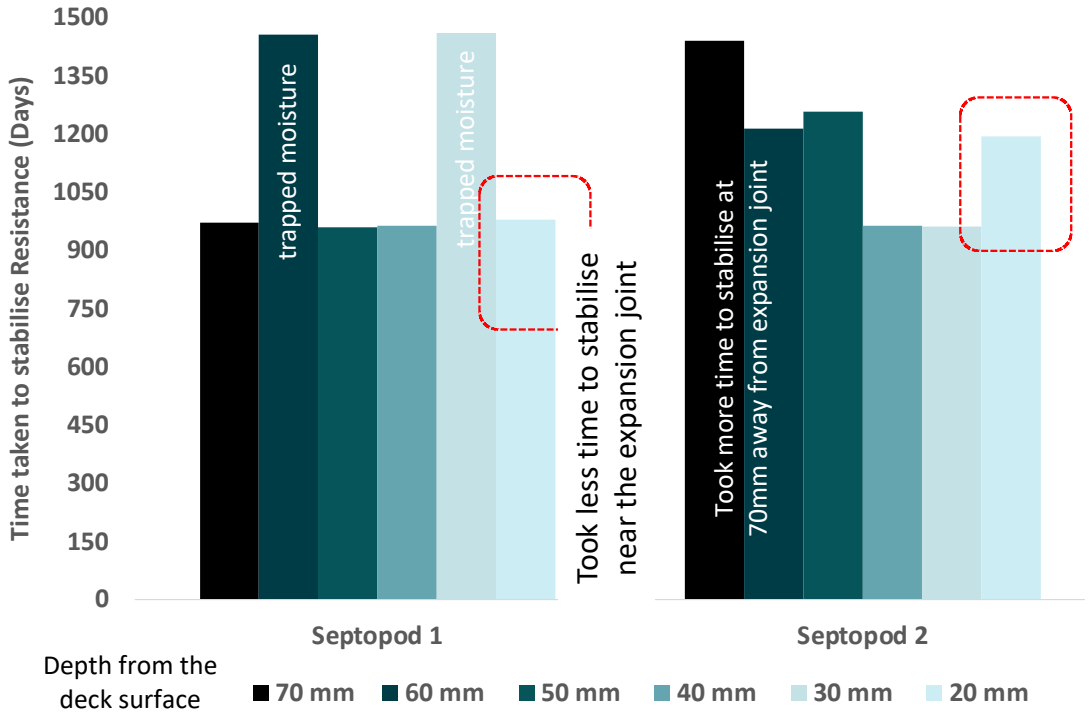
INSIGHTS FROM THE DATA ANALYSIS





aci CONCRETE CONVENTION

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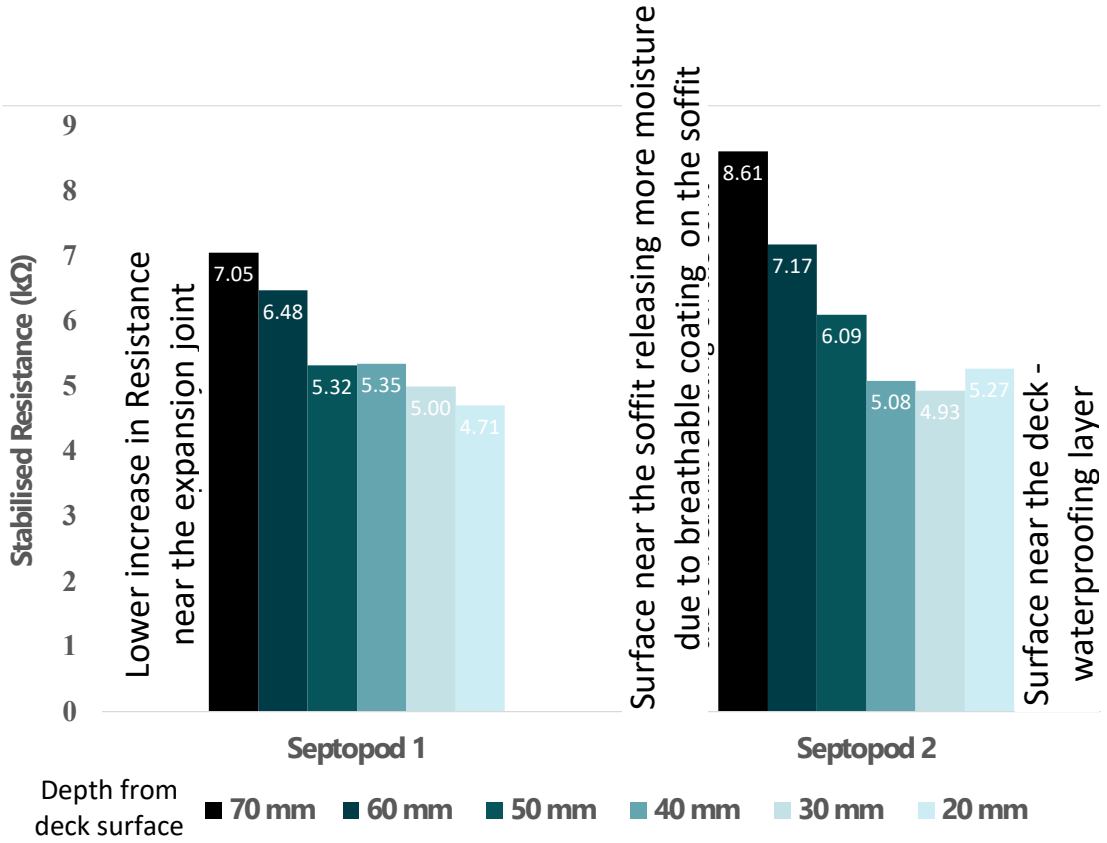
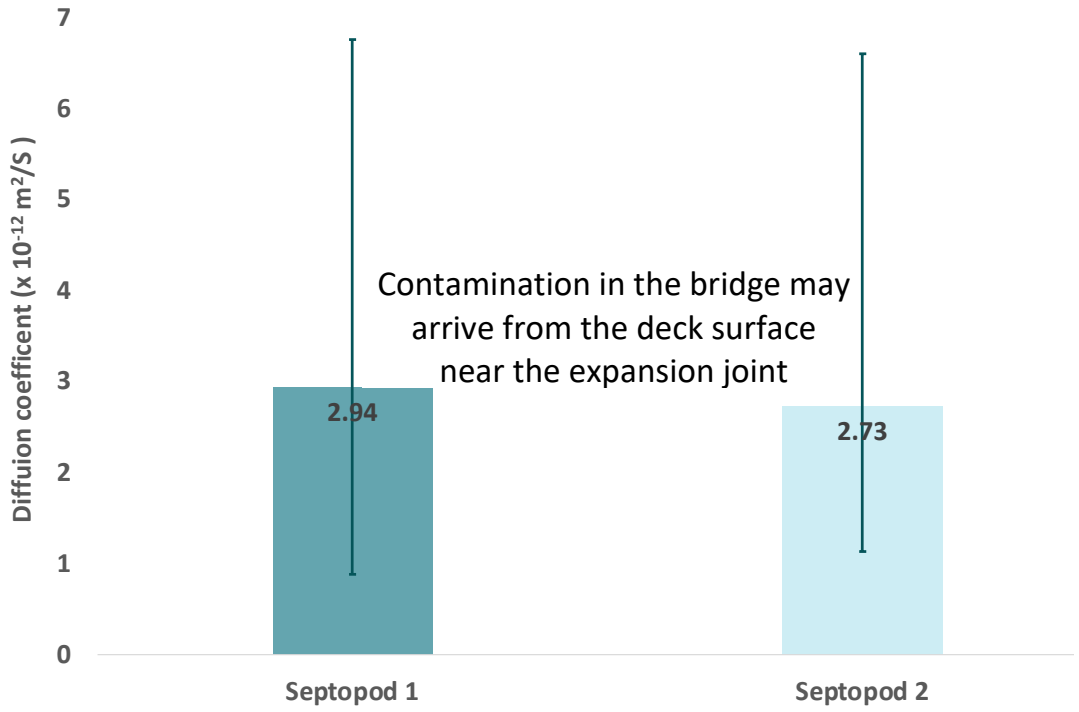
INSIGHTS FROM THE DATA ANALYSIS





Determined D using $\frac{De}{D_0} = \frac{\rho}{\rho_{bulk}}$ which could be used to predict the in-service performance.

CONCLUSIONS

- ❑ Challenges – Handling and managing uncertain large amounts of data.
  - ✓ Demonstrated the need to resort to an automated approach.
- ❑ Developed automated clustering based segmented regression approach
  - ✓ Very efficient and effective approach
  - ✓ Easy to understand and interpret
  - ✓ Reasonable insights on the data
- ❑ The value of Diffusion coefficient lies within the range of $2 – 3 \times 10^{-12}$ m^2/s.
  - ✓ Good quality concrete.
  - ✓ Repaired concrete is performing well.
  - ✓ Demonstrating the property to slow the corrosion process.

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Thank You for listening

Any Questions?

Harshita Garg <cn18hg@leeds.ac.uk>