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“Technical Research and Development for Road Policy Quality Improvement”
Study Summary

No.	Title	Principal Researcher
No. 2023-4	Development of a Maintenance Management System for Concrete Bridges by Integrating Deterioration Imaging with Magnetic and Electrochemical Technologies	Kagawa University Prof. Shinichiro Okazaki

To achieve sustainable and effective bridge maintenance, this research aims to build a system that fuses non-destructive technologies: deterioration imaging of concrete surfaces with magnetic and electrochemical methods. The development process includes validating the accuracy of each technology and integrating them into a cohesive system.

1. Backgrounds and Objects

The deterioration of aging bridges is a critical issue worldwide, posing significant risks of collapse and secondary damage. The internal state of RC and PC bridges is impossible to assess through visual inspection alone until steel corrosion becomes severe enough to cause surface cracking. This creates an urgent need for techniques to rapidly evaluate deterioration by imaging the concrete surface and to assess the corrosion and potential fracture of internal steel reinforcement.

This project aims to develop an advanced bridge maintenance system by fusing three key technologies:

1.Deterioration Imaging: Quantifying surface chloride ion concentration with mid-infrared spectroscopy.

2.Corrosion Evaluation: Non-destructively measuring the corrosion rate of internal steel with the polarization resistance method.

3.Rupture Detection : Identifying steel fractures using magnetic sensing technology.

We will validate the applicability of this integrated system and aim for its implementation both domestically and internationally to create a new standard for bridge management.

2. Activities in Research Period

A. Establishment of a Measurement Method for Chloride Ion Concentration using a Mid-infrared (MIR) Spectroscopic Imaging Device

Kagawa University has successfully imaged chloride ion concentrations on concrete surfaces in a laboratory setting using a proprietary infrared spectroscopic imaging device. This research will examine the applicability of this method in outdoor environments. **Objectives:1.**To develop a prototype device for outdoor use. **2.**To validate the accuracy of surface chloride ion concentration measurements on outdoor concrete specimens. **Target:** To measure the surface chloride ion concentration of concrete with an accuracy of ±10%.

B. Development of Technology to Quantify the Corrosion Rate of Steel in Concrete using an Electrochemical Method

Based on an algorithm developed by Kagawa University that can identify the current distribution range, we will develop a method to evaluate the true polarization resistance by considering various on-site conditions. We will assess its applicability in the field. **Objectives: 1.**To develop an algorithm for evaluating true polarization resistance under conditions of non-uniform moisture content in concrete. **2.**To complete a prototype device. **3.**To examine the applicability of the method on outdoor specimens and actual bridges where steel corrosion is suspected. **Target:** Corrosion rate accuracy of ±20% relative to indoor test results.

C. Advancement of a Steel Rupture Detection Device based on Magnetic Sensing

The magnetic sensing technology developed by Konica Minolta's research group shows reduced detection accuracy in the presence of stirrups or grid-like rebar arrangements. To address this, we will apply the pulse magnetization method to the current Magnetic Flux Leakage (MFL) technique and select the most suitable machine learning algorithm for rupture detection.

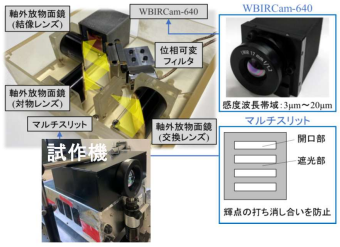
Objectives: To examine the applicability of this method on outdoor specimens and actual bridges where steel corrosion and rupture are concerns. Since real structures often differ from design drawings (e.g., non-uniform stirrup spacing), we will build an algorithm to account for these effects. **Target:** To achieve a steel rupture detection accuracy of 90% for concrete cover up to 15 cm, even in the presence of stirrups.

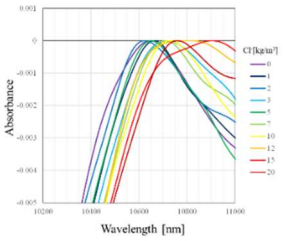
D. Development of an Integrated System

Objective: To build a system that incorporates the results from A, B, and C into bridge inspection data to perform deterioration prediction.

3. Study Results

For Item A, we developed an outdoor prototype device and achieved a measurement accuracy of ±10% for the surface chloride ion concentration on outdoor concrete specimens.





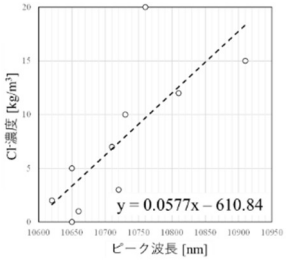
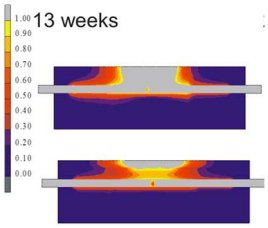
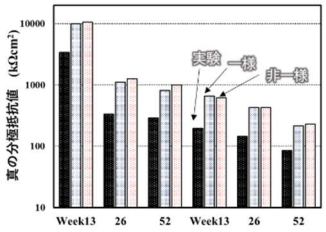


Fig. Prototype device **Fig. On-site measurement** **Fig. Spectrum** **Fig. Calibration curve**

For Item B, we developed a method to determine the true polarization resistance by accounting for current distribution. By integrating this with a chloride-induced deterioration model and the results from Item A, we successfully estimated the time to steel rebar rupture.





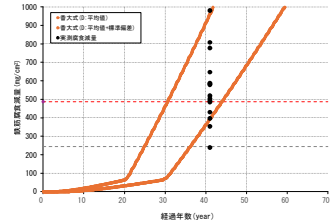
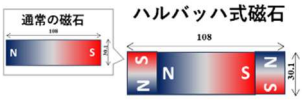


Fig. Current distribution **Fig. Polarization resistance** **Fig. Deterioration prediction**

For Item C, the combination of a triaxial magnetic sensor, a newly developed Halbach array magnet for magnetization, and AI-assisted analysis of the acquired waveforms has enabled detection through a concrete cover of up to 15 cm, even when stirrups are present.



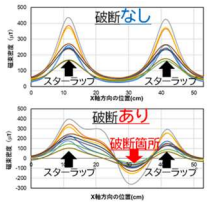


Fig. Device **Fig. The developed magnet** **Fig. Acquired waveforms** **Fig. Rupture detection using AI**

4. Papers for Presentation

・Teshima, K., Okazaki, S., et al. (2024). "Development of an Automatic Identification Technology for PC Steel Rupture Based on Waveforms Acquired by the Magnetic Flux Leakage Method," Proceedings of the Japan Concrete Institute, Vol. 46, pp. 1657-1662. (in Japanese)

・Kadono, T., Okazaki, S., et al. (2024). "Analytical Study on the Effect of Steel Corrosion Progression on the Deformation Behavior of Concrete Surfaces," Proceedings of the 24th Symposium on Repair, Reinforcement, and Upgrading of Concrete Structures, Vol. 24, pp. 617-622. (in Japanese)

・Teshima, K., Okazaki, S., et al. (2024). "Establishment of Technology to Automatically Determine the Presence or Absence of Steel Wires by Magnetic Data of Pre-tensioned Girder PC Steel Using Non-destructive Testing Device," RILEM Bookseries, pp. 144-152.

・Okazaki, S., et al. (2024). "Analysis of Factors of Materials and Exposure Environment Influencing the Prediction Results of a Chloride Ion Diffusion Model," Journal of Japan Society of Civil Engineers (JSCE), Vol. 80, No. 10. (in Japanese)

5. Study Development and Future Issues

In partnership with the Shikoku Regional Development Bureau (MLIT) and other stakeholders, we will collect field data and work towards global adoption.

6. Contribution to Road Policy Quality Improvement

This research contributes to safer, cost-effective, and sustainable road infrastructure, which in turn improves policies and supports public safety.

7. References, Websites, etc.

Further details on Item C can be found at the following link: https://bic.konicaminolta.jp/hihakai/