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

No.	Title	Principal Researcher
No.2021－4	Evaluation of structural safety of PC Bridges by detecting corrosion conditions with high power X-rays and magnetic measurement	Kanazawa Institute of Technology Prof. Yasushi Tanaka

In order to quantitatively evaluate the safety of PC bridges that have been subjected to salt damage, this research aims to develop a Non-Destructive Test (NDT) technique that is able to detect the corrosion status of PC steels inside concrete, and to establish a method to evaluate the residual performance by nonlinear structural analysis in consideration of NDT data.

1. Backgrounds and Objects

Many PC bridges are subject to salt damage caused by air borne salt and anti-freezing salt. In particular, bridges with unfilled grout are suffering from severe deterioration. In this study, a high power and compact X-ray imaging system was developed to detect steel corrosion even in thick concrete members. A magnetic measurement system was also developed to detect steel corrosion quickly in case of small concrete cover. Furthermore, the evaluation method of structural performance for PC bridge was developed and validated by on-site loading tests of PC bridge.

2. Activities in Research Period

In order to reflect research results in practice, existing large PC bridge which was deteriorated by salt attack was selected as research target. The target bridge is the old Myoko Bridge in which many PC steels have corroded due to salt damage. High-power X-ray photography and magnetic measurement were used to detect the corrosion condition of inner steel. The structural performance of the bridge was evaluated by non-linear FEM analysis in consideration of inspection results. The numerical result was verified by on site loading tests. Furthermore, the detection capability of steel corrosion was verified by laboratory tests for the X-ray and magnetic measurements.

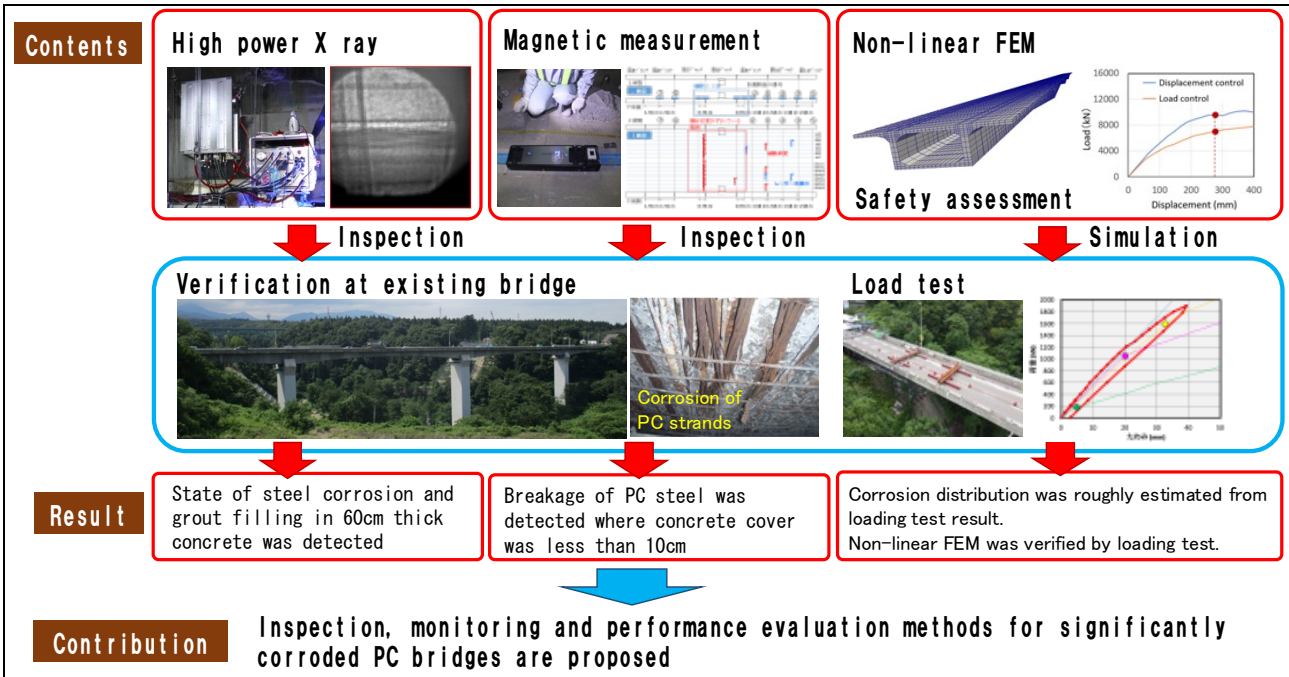
3. Study Results

3.1 Detection of steel corrosion and un-grouted areas using High-power X-rays

High-power X-ray system was applied at Myoko Bridge to detect the corrosion of PC steel and the status of grout filling in thick concrete members. Edge enhancement, contrast adjustment, and filtering were used as image analysis methods. In case that the concrete thickness is less than 60 cm, status of corrosion on the steel and grout filling was clearly determined. If concrete thickness was about 100 cm, the PC steel was visible owing to image analysis. However, the state of corrosion and grout filling in the sheath could not be determined.

3.2 Detection of steel corrosion by triaxial magnetic measurement

Triaxial magnetic measurement was conducted in Blocks 6 to 11 of the first span of Myoko Bridge. Three points of breakage in PC strands were found where endoscopic survey was not examined in past inspection. In addition, four points of steel breakage were detected in the radar measurements which is examined prior to the magnetic measurements.



3.3 Safety evaluation by loading test

Loading test was conducted on the first span of Myoko Bridge. Load - deflection curve showed reduction in stiffness at 1200 kN. This value was coincided with the crack initiation load predicted from the long-term monitoring and numerical analysis. In the early stage of loading test, cracks were initiated and opened at the segment boundaries. Strain measurement using optical fiber was shown to be effective to detect the initiation of concrete cracks.

3.4 Safety Evaluation by Structural Analysis

Multi-scale analysis was conducted to simulate the loading test. 3D FE model of the bridge was created. Steel corrosion model was adopted and the corrosion distribution obtained from past investigations and the non-destructive tests in this study was considered. Crack load at block 8 predicted by numerical analysis was coincided with loading test.

4. Papers for Presentation

・Shizuka Terao, Takahiro Arai, Kiyotaka Toishi and Yasushi Tanaka : Loading test of long span prestressed concrete bridge degraded by salt attack, proceedings of CACRCS2023, 2023.9 (In printing)

5. Study Development and Future Issues

The loading test and FEM analysis conducted in this study can be used for safety assessment of PC bridges with significant steel corrosion. By introducing an automated vehicle, cost and risk of loading test will be reduced. High-power X-rays are expected to be used where inspection of corrosion is difficult for other testing method such as cable-stayed bridges. In both high-power X-ray and magnetic measurement, it is necessary to verify the inspection results by comparing with actual corrosion conditions during demolition work.

6. Contribution to Road Policy Quality Improvement

The structural safety of PC bridges with steel corrosion can be examined by load vehicle tests, long-term monitoring, and performance evaluation developed in this study. As a result, rational maintenance and management can be carried out with minimized risk.