【様式４】

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

| No. | Title | Principal Researcher |
|---|---|---|
| No.31-7 | Research and development of technology for detecting damage in invisible areas by high-sensitivity magnetic non-destructive testing | Okayama Univ. Prof. Tsukada |

We have developed technologies to detect damage and defects such as corrosion, fatigue, and rupture in steel structures in invisible parts by high-sensitivity magnetic non-destructive testing. The inspection method to detect corrosion of steel plates in underwater without removing attached organisms, corrosion of steel pipes buried concrete such as lighting and marker poles, fatigue cracks in welded under painted surfaces, and corrosion of anchor bolts in concrete were developed.

## 1. Backgrounds and Objects

By irradiating a steel structure with a weak extremely low-frequency magnetic field and detecting it with a high-sensitivity magnetic sensor and a new magnetic signal analysis, it is possible to inspect steel plate thinning due to corrosion and cracks in welded parts, which was not possible with conventional methods. Using the developed method, corrosion of steel plates in underwater areas, underground corrosion of lighting poles and sign poles, anchors embedded in concrete, which have been a problem during road maintenance.

## 2. Activities in Research Period

A detection method, that detects the secondary magnetic field from the eddy current generated by applying extremely low frequency AC magnetic field to the inspection target with a highly sensitive magnetic sensor, was developed. A method was also developed to analyze damage such as corrosion and cracks by acquiring magnetic field spectra at multiple frequencies and using magnetic frequency response characteristics. To apply the method to actual steel structures, some inspection systems for various targets were developed and optimized, and system characteristics such as performance, error factors, and applicability were evaluated. The following four technologies were developed as inspection items. (1) Underwater damage detection and evaluation technology: Development of a method to inspect corrosion-induced thinning of steel piers and steel sheet piles from air to the seafloor without removing thick adhesion products. (2) Detection and evaluation technology for damage to buried parts and closed cross-sections: Development of a method to inspect corrosion of lighting and sign poles underground parts in a short time without excavating. (3) Detection and evaluation technology for anchor bolts: Development of a method to detect the presence and status of corrosion of anchor bolts embedded in concrete from the surface of the concrete. (4) Detection and evaluation technology for cracks under coating of welded parts such as stiffener of steel deck:

## 3. Study Results

(1) Underwater damage detection and evaluation technology: For an underwater inspection system using an extremely low-frequency eddy current flaw detection method (ELECT), the waterproofing of the magnetic sensor probe and the 30 m long cable length were developed. Steel sheet piles can be inspected to the bottom of the sea. The relationship between the size of the applied coil and the effect of lift-off was clarified. Based on the information, fluctuations in inspection data due to lift-off, which was a problem of thick adhesion product, were resolved. For example, a 100 mm × 100 mm magnetic sensor probe can be used to inspect up to 80 mm lift-off without affecting the lift-off. (2) Detection and evaluation technology for damage to buried parts and closed cross-sections: The response characteristics of the signal intensity ratios for damage to buried objects and closed sections, which are difficult to visually observe, were clarified depending on the degree

of damage. The corrosion evaluation was performed by normalizing the inspection data to evaluate corrosion independent of the thickness of the plate. It was also shown that significant damage can be detected on actual lighting and sign poles without excavation. The frequency characteristics of magnetic noise caused by vehicles, which is a problem on roads, were clarified, and the inspection frequency that is less affected by magnetic noise was clarified in this inspection. Furthermore, it was found that ELECT can be used to screen ribs for fatigue damage. (3) Detection and evaluation technology for anchor bolts: A dynamic magnetic field analysis and a basic experiment were performed on a simulation model of a steel bar with sectional defects and corrosion products due to anchor bolt corrosion, and the possibility and optimization of a magnetic inspection method were achieved. Furthermore, a measuring head was fabricated to be applied to the actual structures, and the optimum arrangement conditions of the excitation and detection coils were evaluated. (4) Detection and evaluation technology for cracks under coating of welded parts: A method was developed to clearly detect fatigue cracks in welds even with a lift-off that assumes the thickness of the anti-corrosion coating applied to steel bridges. The characteristics of the signal patterns obtained by high-sensitivity magnetic nondestructive testing and the method of organizing them were investigated, and demonstrated its applicability as a screening inspection.

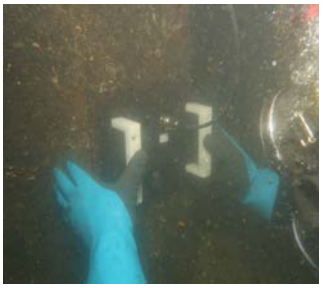

Fig.1 Underwater inspection using a large magnetic sensor probe.

Fig.2. Inspection of corrosion under ground level of sign pole.

## 4. Papers for Presentation


1) K. Tsukada, et al., Magnetic thickness measurement for various iron steels using magnetic sensor and effect of electromagnetic characteristics, AIP Advances 12, 035109-1-4 (2022)
2) T. Ohnishi, et al., Attempt on detection of fatigue crack by high-sensitivity magnetic non-destructive inspection, Journal of Structural Engineering, Vol.67A, pp.479-487 (2021)
3) Y. Miyamoto et al., An investigation on crack detection in welded part by high-sensitivity magnetic non-destructive inspection, Preprint of 76th JSCE Annual Meeting, I-139 (2021)
4) J. Uesugi, et al., Basic study on detection of corrosion in anchor bolt in concrete using high sensitivity magnetic sensor with phase sensitive detection of low frequency AC magnetic field response, Proceedings of the Concrete Structure Scenarios, JSMS, Vol.21, pp.343-348 (2021)


## 5. Study Development and Future Issues

Regarding the technique for detecting and evaluating the damage in the underwater area, the inspection from the land completely by the mechanical arm shown as the next-generation inspection method is important from the viewpoint of the shortage of divers and the cost, and it is necessary to continue the development. Regarding the technology for detecting damage to buried objects and closed cross-sections, it has become possible to inspect corrosion underground of sign and lighting poles without excavation. We would like to develop more suitable inspection systems that can be applied to various shapes using the developed methods. Regarding the technology for detecting and evaluating anchor bolts embedded in concrete, the possibility has been shown to evaluate the presence and status of corrosion from the surface of concrete to the extent of 50mm length. We would like to develop an inspection system that can be applied to actual structures hereafter.

## 6. Contribution to Road Policy Quality Improvement

Regarding the technique for detecting and evaluating the damage in the underwater area, it is possible to obtain the same inspection results by magnetic inspection, which does not require surface treatment, as compared with the ultrasonic inspection that is currently performed by divers, which requires surface treatment. Regarding the technology for detecting damage to buried objects and closed sections, it has become possible to inspect corrosion damage underground without excavation. The developed technology will improve the speed of corrosion inspection of underwater and buried parts, facilitate the determination of the need for repair, and reduce the cost of maintain.

## 7. References, Websites, etc.

None