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研究課題名

加振レーダによる **RC** 部材の鉄筋可動性に着目した定量鉄筋腐食評価技術の革新

Innovation in Quantitative Rebar Corrosion Evaluation Technology Focusing on the Movability of Rebar in RC Members Using Vibro-Radar

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Abstract

Many infrastructure facilities such as roads, bridges, and tunnels, which are closely tied to daily life, were constructed during the period of rapid economic growth and are now approaching 50 years old. For example, while 30% of Japan's 730,000 road bridges are over 50 years old and still in use, this percentage is estimated to increase to 55% in 10 years. The maintenance costs associated with aging infrastructure facilities are becoming a societal issue. Furthermore, following the 2014 Sasago Tunnel roof collapse accident, infrastructure facilities became subject to mandatory close-range visually-based inspections every five years. These periodic inspections assign bridges to deterioration stages I through IV. However, approximately 70,000 bridges still fall categories III and IV, requiring subsequent repairs. However, during periodic inspections after repairs, preventive maintenance category II often transits to the category III due to aging deterioration. If a system can be developed to evaluate reinforcement corrosion in reinforced concrete (RC) bridges—which account for the majority of deterioration factors—in a simple, rapid, and quantitative method, it is expected to become an innovative technology for developing efficient preventive maintenance plans for infrastructure structures.

Generally, when rebars corrode and rust develops, the bond strength between the rebars and concrete is expected to decrease, increasing the movability of the rebar. Therefore, we have developed a vibro-radar method that can non-destructively and quantitatively measure the vibration displacement of rebars with spatial resolution of several centimeters, identified using Doppler radar technology, while forcibly vibrating the rebars by applying magnetic field alternating. We have confirmed that as corrosion progresses, the vibration displacement increases to approximately four times that of the sound state. On the other hand, challenges for practical application of this method include the shallow detectable distance of approximately 6 cm and the difficulty of scanning measurements, as each point takes about one second. Furthermore, it is necessary to clarify the relationship between vibration displacement and rebar corrosion rate, the corrosion threshold, and the mechanism for increasing vibration displacement. Therefore, this research aims to develop a vibro-radar scanner capable of continuously scanning rebar vibration displacement at 10 cm/s to a depth of approximately 10 cm, and to develop equipment that can quantitatively evaluate the spatial distribution of rebar corrosion in actual field conditions based on rebar vibration displacement.

As a result of preparatory research, we demonstrated that continuous scanning enables the measurement of rebar vibration displacement distribution in the actual field, with a speed of approximately 10 cm/s. In the main research, by examining the shape of the excitation coil, we optimized it from the conventional semi-circular arc coil (8 kg, applied current 10 A) to a solenoid coil (4 kg, applied current 7 A). Furthermore, using impulse Doppler radar technology, we achieved a system capable of continuously scanning the vibration displacement distribution of reinforcing bars up to a depth of 10 cm at 10 cm/s. Additionally, we developed a portable vibro-radar device easily applicable to field experiments on actual bridges, enabling demonstration tests on six bridges in Gunma and Niigata Prefectures.

Additionally, 30 types of RC specimens were fabricated by varying the rebar diameter and concrete cover. The dependence of rebar vibration displacement on rebar diameter and concrete cover in the sound state, as well as the specimen-derived variation in vibration displacement, were evaluated. The results showed that the average vibration displacement decreased exponentially at a rate of 0.8 times per cm of cover thickness and decreased as the rebar diameter increased. Furthermore, the variation rate of the vibration displacement was approximately 11%. Therefore, by setting the corrosion threshold at 33%—three times the variation rate relative to the average vibration displacement—it was found that even minor corrosion could be evaluated.

Furthermore, X-ray CT was used to investigate the mechanism by which increased vibration displacement of the vibro-radar results from the increase in corrosion products. Furthermore, X-ray transmission images of corroded reinforcing bars under applied magnetic fields revealed that γ-Fe_2O_3, a magnetic corrosion product densely deposited around the bar poles, moved more significantly than the bars themselves in response to the magnetic field. This finding led to the conclusion that this movement constitutes the mechanism behind the increased vibration displacement.