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DEVELOPMENT OF ELECTROMAGNETIC METHOD TO EVALUATE THE CORROSION OF STEEL REBAR

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ABSTRACT

We developed an electromagnetic method to evaluate the corrosion of steel rebar. AC magnetic field was produced by an excitation coil when AC current flow in it. Then, eddy current was induced in the surface of the steel rebar. A detection coil was used to measure the magnetic field produced by the eddy current. The signal after the amplifier was sent to a lock-in amplifier. From the lock-in amplifier, two signals were obtained: X signal (the same phase signal with the excitation current) and Y signal (90 degree phase difference signal with the excitation current). From the slope of the plotted X-Y graph using the X and Y signals, the corrosion of the steel rebar can be judged. We developed a small compact system for the corrosion evaluation of steel rebar, which will be suitable for the field experiments.

Keywords: electromagnetic, steel rebar, corrosion

1. INTRODUCTION

The corrosion of steel reinforcing bar (Rebar) in concrete structures not only reduces the strength of the concrete structures and also causes the broken of the concrete due to the volume increasing of the corrosion products. The periodic inspection of the steel rebar in concrete is necessary and important. Knowing the conditions of the steel rebar, such as the location, the diameter, and the corrosion of steel rebar, is important for the safety evaluation of concrete structures.

Magnetic flux leakage (DC field) method [1], electromagnetic induction (AC field) method [2], Micro-wave radar system [3], and thermography technology [4] have been used to evaluate the break, the location, or the corrosion of the steel rebar in concrete.

The magnetic flux leakage (MFL) method is mainly used to detect breaks in prestressing steel of pretensioned and post-tensioned concrete structures. The microwave radar systems can be used to detect the position and the covering depth of the steel rebar, however, the water or moisture in the concrete structures may influence the detection accuracy of the detection and it is difficult to detect the second layer steel rebar for the concrete with steel rebar grid. Thermography technology is not suitable to detect the steel rebar with deep depth.

Compared with other methods, the low frequency electromagnetic induction method has the advantages of low cost and easy operation and fewer influence from the moisture of concrete structures. We developed electromagnetic evaluation methods to detect the depth, the diameter and the corrosion of steel rebar.

2. EXPERIMENTAL SETUP

When corrosion happened with the steel rebar in concrete, corrosion products were produced on the surface of the steel rebar. The corrosion products have different electrical conductivity and permeability, so the electromagnetic responses of the corrosion products are different from that of the steel rebar. Therefore, it is possible to evaluate the corrosion of steel rebar by measuring the electromagnetic response.

Fig. 1 shows the experimental setup for the corrosion evaluation of steel rebar using electromagnetic method. The excitation coil was used to produce the AC magnetic field, and eddy current was induced in the steel rebar. The detection coil was used to measure the magnetic field produced by the steel rebar. The lock-in amplifier was used get the X and Y signal, where the X signal was the same phase signal with the excitation magnetic field, and the Y signal was the 90 degree phase different signal with the excitation magnetic field. In our experiments, the frequency of the excitation AC magnetic field was about 80 kHz, the diameter of the excitation coil was 3 cm with 100 turns, and the detection coil was 1 cm and 100 turns.

Fig. 2 shows the compact system of corrosion evaluation of steel rebar. The excitation coil, the detection coil, the amplifier and the lock-in amplifier were put in a small box of about 9cm□12cm□7cm. The AD board was put in another box. Only one USB cable was used to connect the AD board with a computer. Both the power of the system and the data were transferred by the USB cable. The total power consumption of the system was about 0.5 W.

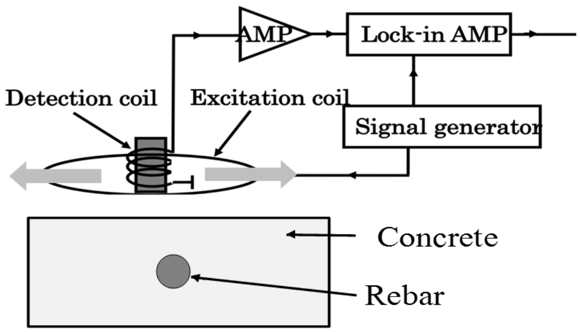

FIGURE 1: EXPERIMENTAL SETUP FOR THE CORROSION EVALUATION OF STEEL REBAR USING ELECTROMAGNETIC METHOD.

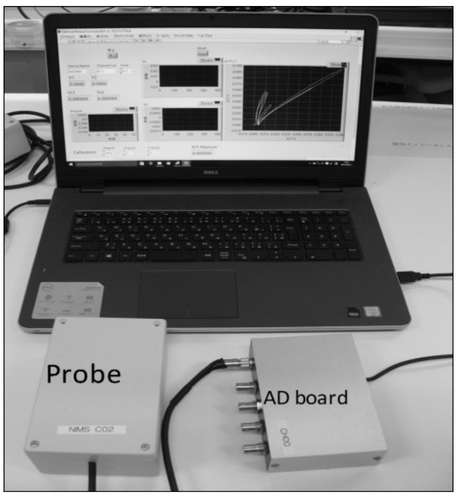

FIGURE 2: COMPACT SYSTEM FOR THE CORROSION EVALUATION OF STEEL REBAR.

3. RESULTS AND DISCUSSION

Fig. 3 shows the samples of steel rebar with different corrosion levels. The diameter of the steel rebar was 16 mm. The steel rebar “a” had no corrosion; steel rebar “b” had a little corrosion, there are some corroded dots on the surface the steel rebar; steel rebar “c” had big corrosion, the thickness of the corroded layer was about 0.1 mm and steel rebar “d” had severe corrosion with the thickness of the corrosion layer of about 1 mm.

We scanned the steel rebar using the electromagnetic system. Fig. 4 shows the signals of steel rebar when the covering depth was 5 cm. X-Y graphs were plotted using the X and Y output signals of the lock-in amplifier. The slopes were different for the steel rebars with different corrosion levels. The absolute value of $\Delta Y/\Delta X$ increased with the corrosion level. Fig. 5 shows the values of $\Delta Y/\Delta X$ for the steel rebars at different depths. They were mainly determined by the corrosion levels and had less relation with the covering depth. This result proved that it was possible to evaluate the corrosion of steel rebar using this electromagnetic method. We also did some field experiments to check the corrosion of steel rebar in concrete bridges.

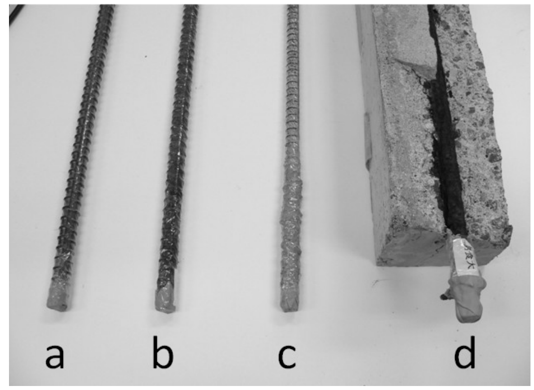

FIGURE 3: SAMPLES OF STEEL REBAR. a: NO CORROSION. b: A LITTLE CORROSION. c: BIG COROSION. d:SEVERE CORROSION.

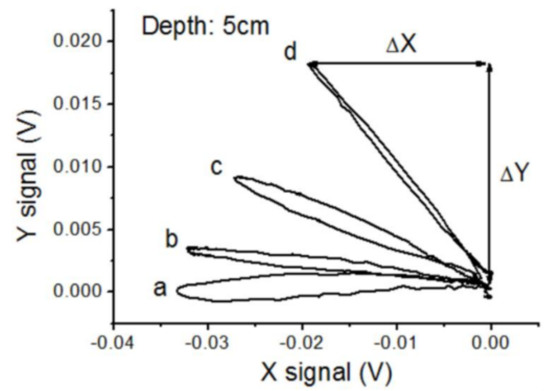

FIGURE 4: THE X-Y GRAPH OF THE X, Y SIGNALS OF STEEL REBARS WITH DIFFERENT CORROSION LEVELS.

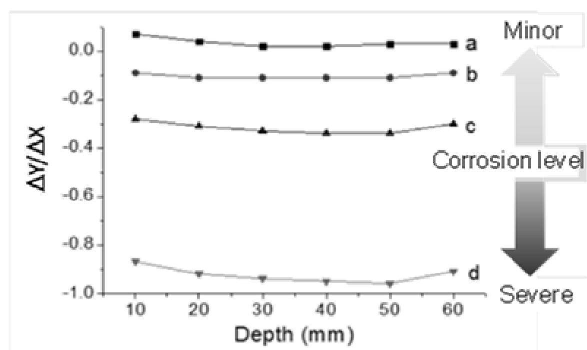

FIGURE 5: THE VALUES OF of $\Delta Y/\Delta X$ FOR THE STEEL REBARS AT DIFFERENT DEPTH.

4. SUMMERY

We developed electromagnetic methods to evaluate the corrosion of steel rebar. Using the frequency about 80 kHz and the X, Y output signals of the lock-in amplifier, the corrosion of steel rebar can be evaluated using the slop of the X-Y graph. We will do field experiments using our electromagnetic system to evaluate the corrosion of steel rebar in railway concrete bridges.

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