電磁パルス音響法を用いた鉄筋コンクリートにおける鉄筋腐食の評価

Evaluation of Rebar Corrosion in Reinforced Concrete using Electromagnetic Pulse-induced Acoustic Testing Method

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This paper proposed the evaluation of rebar corrosion in reinforced concrete by an electromagnetic pulse-induced acoustic testing method. A strong pulsed electromagnetic force is applied to the specimen, and the rebars will generate the elastic waves. The difference in the bonding force between the rebars and concrete depending on rust is evaluated based on the intensity and waveform variation of elastic waves. In this study, the rusted and un-rusted rebar specimens are prepared, and the AE sensor is placed in different positions. The results show that whether rebars have rust or not does not affect the occurrence of elastic waves. In addition, the maximum signal amplitudes of the rusted and un-rusted rebar specimens were different. The vibration of the rebars appears to be affected by the presence of rust.

Keywords: Electromagnetic Pulse-induced Acoustic Testing, Nondestructive testing, Elastic wave, Concrete structure, Corrosion evaluation

1. Introduction

In the ten years after the accident at Fukushima nuclear power plant, there are still frequent natural disasters such as earthquakes hitting nuclear power plants. To prevent the damage caused by natural disasters, it is necessary to ensure the integrity and reliability of concrete structures such as reactor buildings. Most of the causes of the strength reduction of concrete are the change of bonding conditions between concrete and rebars. Therefore, the bonding condition must be evaluated.

Electromagnetic pulse-induced acoustic testing (EPAT) [1] appears to be a suitable method to evaluate the bonding condition between concrete and rebars. EPAT is the electromagnetic nondestructive evaluation method of composite materials consist of non-conductive and conductive materials. In EPAT, the pulsed electromagnetic field is excited by the exciting coil from outside the specimen without contact, thereby directly exciting elastic waves on the conductive material inside the composite. The material properties and conditions of composites are evaluated by acquiring the elastic wave signals with acoustic emission (AE) sensor. From this mechanism, EPAT works similarly to the hammering test, which is widely used in concrete evaluation. Unlike the hammering test, EPAT couldn't deteriorate the material properties because it generates elastic waves without contact. In addition, EPAT has good data reproducibility because the pulsed electromagnetic force is easy to be controlled. In addition, the effects of surface conditions of conductive materials can be avoided by EPAT because conductive materials vibrate themselves to generate elastic waves. In the previous study, the compressive strength of concrete structures has been estimated by analyzing the change in the propagation velocity of elastic waves by EPAT [2]. EPAT showed good reproducibility and quantitative analysis ability. For the next step of the EPAT study about reinforced concrete, we have been focused on the possibility of EPAT as the evaluation method of the bonding condition of a concrete matrix and rebars of a reinforced concrete. The aim of this study is to investigate bonding conditions between concrete and rebars in reinforced concrete according to the different strengths of elastic waves generated in different bonding conditions.

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2. Experiments

Figure 1 shows the setup of the EPAT system. The pulsed voltage is applied to the exciting coil, and the pulsed magnetic

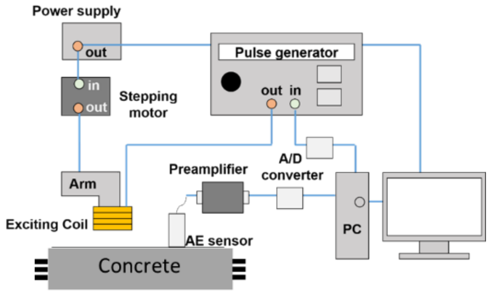


Fig.1 Schematic illustration of EPAT system.

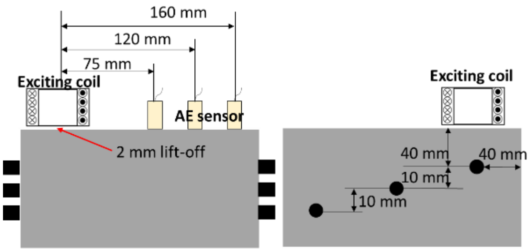
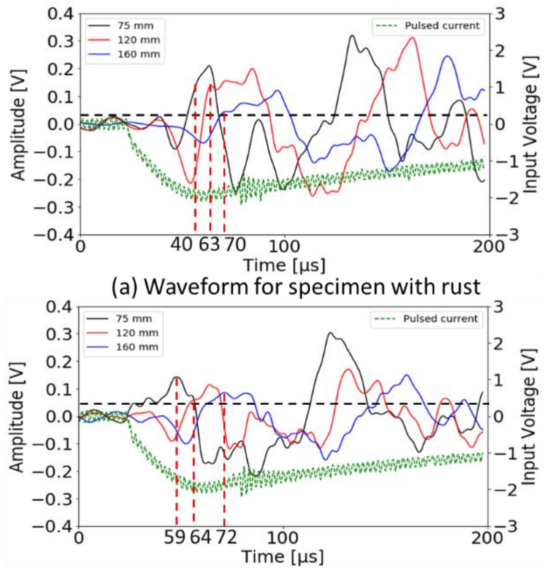


Fig.2 Schematic illustration of the concrete specimen.



(a) Waveform for specimen with rust

(b) Waveform for specimen without rust

Fig.3 Received signals in different distances.

field is excited. The magnetic field induces the pulsed eddy current in the rebars inside the concrete. Then, the elastic wave is generated by the rebars, and it will be acquired by the AE sensor. The starting time t = 0 is defined as the time before 24 µs from when the voltage is applied. The inductance of the exciting coil is 6.8 µH, and the lift-off is set as 2.0 mm.

Figure 2 shows the schematic illustration of the reinforced concrete specimen. In this study, two kinds of specimens are prepared by using rusted rebars and un-rusted rebars. Both the specimens have the same size of 300 × 300 × 30 mm^3 and the same rebars positions. The distance of the exciting coil and the AE sensor is varied to 75 mm, 120 mm, and 160 mm to investigate the signal change due to the position of the AE sensor.

3. Results and discussions

Figure 3 shows the obtained signal of the AE sensor placed at different positions under the same specimen. The threshold value of the signal is set to 0.05 V because the maximum amplitude of white noise is 0.04 V. The time when the first peak appeared is defined as the signal occurrence time. For the rusted rebar specimen, the occurrence times when the distances between the exciting coil and the AE sensor were 75 mm, 120 mm, and 160 mm, were 40 µs, 63 µs, and 70 µs, respectively. For the un-rusted rebar specimen, these were 59 µs, 64 µs, and 72 µs, respectively. This result suggested that rust in rebars does not affect the occurrence time of elastic waves.

Concerning the maximum amplitude of AE signals, when the distance between the exciting coil and the AE sensor was 75 mm, the maximum signal amplitude of rusted rebar specimen and un- rusted rebar specimen were 0.24 V and 0.32 V, respectively. When the distance was 120 mm, these were 0.23 V and 0.31 V, and when the distance was 160 mm, these were 0.21 V and 0.32 V, respectively. The maximum AE signal amplitude showed almost the same value regardless the distance of the exciting coil and the AE sensor for both specimens, but the signal amplitudes of the rusted and un-rusted rebar specimens were different. The vibration of the rebars appears to be affected by the presence of rust. These results suggested that the EPAT can investigate the deterioration of the reinforced concrete nondestructively by evaluating the maximum signal amplitude.

4. Summary

(1) The occurrence time of elastic waves appears not to be affected by the presence of rust in rebars.

(2) The maximum signal amplitudes of the rusted and un-rusted rebar specimens were different. The vibration of the rebars appears to be affected by the presence of rust.

References

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