Ultrasonic guided wave for monitoring corrosion of steel bar

Xi Liu, Lei Qin* and Bosheng Huang

School of Civil Engineering and Architectural Engineering, University of Jinan, Jinan 250022, China

*Corresponding author e-mail: cea_qinl@ujn.edu.cn

Abstract. Steel corrosion of reinforced concrete structures has become a serious problem all over the world. In this paper, the work aims at monitoring steel corrosion using ultrasonic guided wave (UGW). Ultrasonic guided wave monitoring is a dynamic and non-destructive testing technology. The advantages of ultrasonic guided wave monitoring for reinforcement corrosion are real-time, online and continuous. In addition, it can judge the different stages of steel bar corrosion, which achieved non-destructive detection.

1. Introduction

Reinforced concrete (RC) are the most widely used materials all the world. The corrosion behavior of steel in concrete is an engineering issue that have become one of the major durability problems. Thus, it is necessary to monitor the corrosion of steel bar. There are many methods for corrosion monitoring, such as acoustic emission [1], resistance probe [2] and Anode-Ladder method [3-5], ultrasonic guided wave [6-8], etc. Ultrasonic monitoring has been studied for a long time, because it has many advantages. Na, Kundu and Ehsani made a set of reinforced concrete beam specimens with various bond levels and tested using guided waves at low and high frequencies [9]. Pantazopoulou and Papoulia developed an analytical model for cracking due to corrosion product accumulation using a smeared crack approach [10]. This paper mainly studied the degree of reinforcement corrosion by the amplitude of ultrasonic guided wave.

2. The Experiment

2.1. The Preparation of the Sensor

The diameter of piezoelectric ceramic piece was 10mm, and its diameter was 1mm. And coaxial conductors were welded onto positive and negative electrode of piezoelectric ceramic piece, respectively. In order to reduce the interference of noise, the wire which has shielded noise in the process of welding receiving sensor can be left in advance. And BNC can be welded on another end of wire, which can be convenient to contact with signal generator and oscilloscope. The piezoelectric ceramic pieces are indicated in Figure 1.
2.2. Materials
Concrete was not used in this study to avoid possible interaction with large aggregates. The mortar mix had the following weight proportions of sand, cement, and water: 2:1:0.55. The specimens of dimensions 40×40×120mm were cast. 10mm diameter and 140mm length plain mild steel bar was embedded in the center of the beam at the time of casting.

2.3. Accelerate Corrosion
In order to accelerate corrosion, it is necessary to partially submerge the reinforced mortar specimens in a bath of salt water (5% NaCl). In order to accelerate the rebar corrosion, the positive lead of a power supply was attached to the rebar, the negative lead of a power supply was attached to the surrounding copper bar. And the voltage is 2V, the current is 0.01A. One end of bar was pasted emission piezoelectric transducer, and another end of bar was pasted receiving piezoelectric transducer. Electrical wire was pasted in the middle of reinforcement.

2.4. The Process of the Experiment
The transducers were attached at the two ends of the bars by means of a holder and a coupling gel between the bar and the transducer. The pulse transmitted at the other end of the bar was recorded using a receiving transducer. A low frequency of 100kHz had negligible loss of signal due to material absorption from dispersion curve. This mode showed significant axial displacement at the interface and is a surface seeking mode. Hence, 100kHz was chosen to assess the interfacial changes. The input signal voltage amplitude was ±5V, and display devices could show ultrasonic guided waveform clearly. After applying an electric current, the amplitude of ultrasonic guided wave signal was measured. The data was recorded every 6 hours until getting steady. The experiment equipment was showed as Figure 2.

![Figure 1. The piezoelectric ceramic piece](image1)

![Figure 2. The diagram of ultrasonic guided wave monitoring system](image2)
3. Results and Discussions

Time domain signal of ultrasonic guided wave using oscilloscope could be recorded every 3 hours until steady. Representative wave was shown as Figure 3.

![Figure 3](image)

**Figure 3.** Time domain signatures at different instants of the samples
Figure 4. The trend of the amplitude of ultrasonic guided wave

The trend of the amplitude can be seen in Figure 4. From the beginning to 50h, the trend of the signal was keeping decreasing. The energy of ultrasonic guided wave leaked into the surrounding mortar, which leaded to energy attenuation. It can be seen that the corrosion started to develop, but the crack did not appear. The lowest point appeared on 50h. The lowest amplitude was 464 mv, and the internal crack that fell under human sight or observation started to occur. And then, from 50h to 110h, the trend was keeping increasing, and the interface of steel bar and concrete emerged to separation. At this time, cracks started to occur in the surface of the mortar. From 110h to the end, the amplitude kept steady.

4. Conclusion

In this paper, piezoelectric ceramic piece was used as emission transducer and receiving transducer. The experiment was carried out to monitor different stages of the corrosion process using ultrasonic guided wave. The amplitude of ultrasonic guided wave could response the degree of reinforcement corrosion in RC structure effectively.

Acknowledgments

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