2P2-15

Proceedings of Symposium on Ultrasonic Electronics, Vol. 36 (2015)
5-7 November, 2015

# The detection of reinforced concrete crack caused by corrosion using non-contact acoustic inspection method
非接触音響探査法による鉄筋腐食ひび割れの検出に関する検討

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## 1. Introduction

The asset management to a dilapidated infrastructure is advocated. However, actually in most cases, we handle after a defect is found. Prior maintenance cannot be performed up to now. Particularly, degradation of reinforced concrete (RC) structure, which is considered to be maintenance-free from conventional, is becoming remarkable. Degradation of RC structure is caused mainly by corrosion degradation of an internal steel rod. So we need the nondestructive inspection technique which quantitatively evaluates the deterioration degree from a long distance. On the other hand, our laboratory has demonstrated that the accuracy of our inspection method is equivalent to the hammer method. Our non-contact acoustic inspection method uses the airborne sound wave and laser Doppler vibrometer (LDV). This time we examined whether the internal crack caused by reinforced rod corrosion can be detected from a long distance with the non-contact acoustic technique.

## 2. The non-contact acoustic inspection method using flexural resonance

The non-contact acoustic inspection method[1)] (hereinafter referred to as our method) has studied mainly as a substitute for the hammering test to the concrete surface in a tunnel. As shown in Fig. 1, the long-range acoustic device (LRAD) generates a strong sound vibration and gives vibrational energy to an object structure. We measured flexural resonance vibrations occurred at the surface of cave or crack defects inside the concrete structure using the laser Doppler vibrometer (LDV) or the two-dimensional scanning vibrometer (SLDV) with high sensitivity. This method uses the flexural resonance which is theoretically the same as the hammer method. So it can essentially be substituted for the hammer method. In the hammer method a skillful inspector beats the concrete surface by a hammer and distinguish a defect from healthy parts. Therefore experience is needed. Our method has an advantage that a quantitative measurement is recorded as a vibration velocity and we can measure more than 5m apart from a measuring surface. Our method is non-contact and nondestructive inspection method. Degradation such as a cave or a crack of concrete structures (a bridge, a tunnel and a dam, etc.) can be detected.

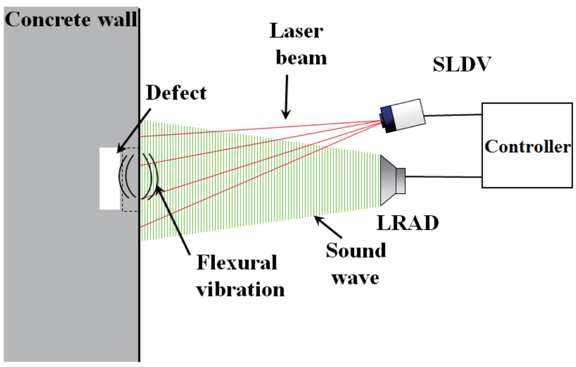


**Fig.1. The non-contact acoustic inspection method.**

## 3. Inspection experiment using test object

### 3-1 The test object involved the steel rod corrosion

A steel rod corrosion test object (100cm×45cm×20cm) is shown in Fig. 2. As shown in this figure, four steel rods 16 mm in diameter are arranged in depth of 50 mm from the concrete surface. The test object was dipped in salt solution and each steel rod was turned on electricity while changing the turning-on-electricity time. The corrosion degree of a steel rod was changed according to the length of time. Here, the degree of corrosion of the steel rod is the order of number (0) <(1) <(2) < (3) in Fig. 2.

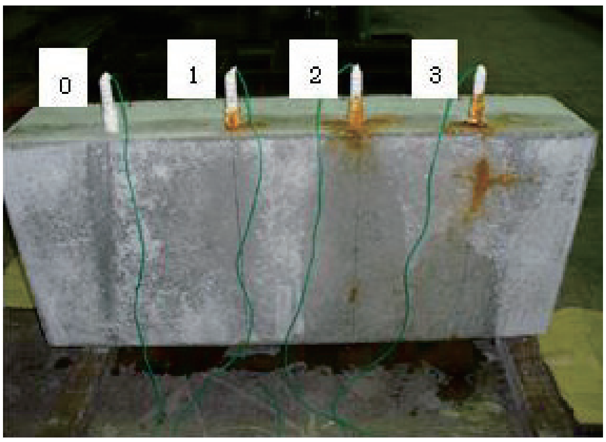


**Fig.2. A steel rod corrosion test object.**

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### 3-2 Experimental setup

An experiment setup is shown in Fig. 3. LRAD (LRAD Corp., LRAD-300X) was used as a sound source, and sound pressure was adjusted so that the maximum sound pressure on the surface of concrete can be set to about 100 dB. As a sound wave, the tone burst wave (pulse length ; 3ms, frequency interval; 200 Hz, pulse interval ; 50 ms) of 500 to 7100 Hz was used[2]. As shown in Fig. 4, by SLDV (Polytec Corp., PSV400- H4), the oscillating speed of a part of concrete surface was measured at grid points spread in a measuring surface (about 5 cm pitch, 10 × 16 points and 5 times average). The concrete exfoliation caused by corrosion is indicated by a red line in the upper right on Fig. 4.

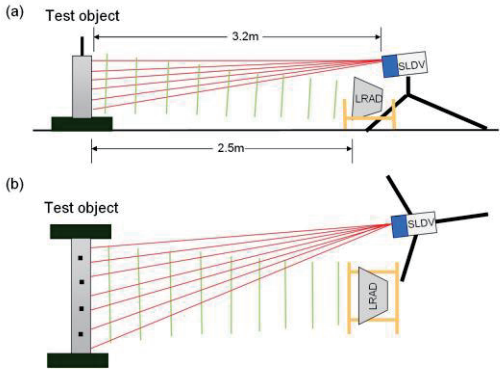


**Fig.3. Experimental setup.**
**(a) Side view, (b) Upper view**

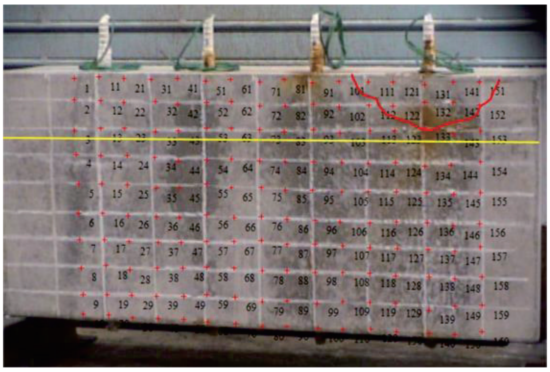

**Fig.4. Photograph of the test object.**

### 3-3 Experimental result

In order to evaluate an experimental result, the influence of various kinds of reflection, reverberation, etc. was reduced by using the time and frequency gate to vibration velocity waveform measured by SLDV. The obtained amplitude spectrum was squared and integrated. Then a vibrational energy was calculated at each measured point. In order to remove the resonance frequency of a SLDV head, the vibrational energy was calculated by the frequency range 1200 Hz - 8192 Hz. The vibrational energy ratio was calculated regarding that the minimum vibrational energy was a standard healthy part among measuring points. Furthermore, the spectrum entropy in each measured point was calculated, and a measurement poor point was detected[3]. A distribution of vibrational energy ratio is shown in Fig. 5.

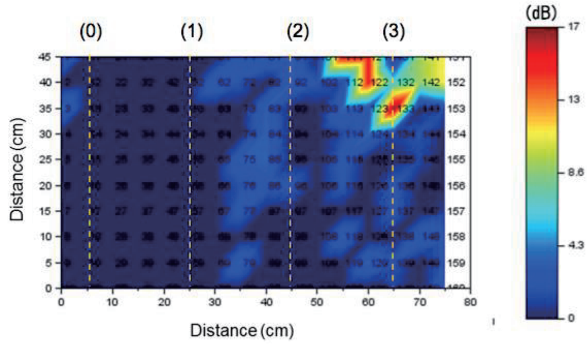


**Fig.5. The distribution of vibrational energy ratio.**

On and near the steel rod (3) in the upper right of Fig. 5, the vibrational energy becomes higher. It is almost at the same position as a crack shown in Fig. 4. The vibrational energy of the steel rod (2) is lower than that of the steel rod (3). In an area shifted to the left from vertical direction of the steel rod (2), the vibrational energy is a little higher than that of the surrounding. In order to ascertain, the test object was cut at the position of the yellow line of Fig. 4. A crack caused by corrosion of the steel rod was obviously confirmed. On the other hand, there is not a corrosion crack in the area of a steel rod (0) and (1). In Fig.6, we can find a crack 0.1 mm in width around the steel rod (2) and a crack of approximately 0.2 mm in width around the steel rod (3). A red crack line towards the concrete surface is shown respectively in the rod (2) and (3) of Fig.6. A surface peeling develops along a blue line in the upper area of the steel rod (3) of Fig. 6.

**Steel rod(2)** **Steel rod(3)**
**Fig.6. The cut cross section of test object.**

### 4. Conclusion

By the non-contact acoustic method, the exfoliated part of reinforced concrete caused by corrosion of a steel rod can be detected. A crack along the longitudinal direction of the reinforcing steel rod can be detected to a size on the order of approximately 0.2 mm in width. In the future, the detectable range of a crack is due to be verified.

**References**

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