Construction and Building Materials 162 (2018) 908–913

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Virtual Special Issue
AE and Related NDT for Damage Evaluation of Civil Structures

Efficient damage inspection of deteriorated RC bridge deck with rain-induced elastic wave

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HIGHLIGHTS

- The interior cracks are detected efficiently by measurement over a short period of time.
- Rain-induced signals, which are usually considered to be noise, are used to detect the cracks.
- Effectiveness of our method has been verified by the inspection of an in-service highway bridge.
- Coring results showed that our analysis results using rain-induced signals were correct.

ARTICLE INFO

Article history:
Received 15 September 2017
Received in revised form 16 January 2018
Accepted 19 January 2018

Keywords:
Acoustic emission
Non-destructive testing
Bridge
Concrete
Crack
Inspection
Rain

ABSTRACT

To maintain a large number of bridges, efficient inspection methods are needed. We have developed a new and efficient method for inspecting reinforced concrete bridge decks by using acoustic emission (AE) monitoring. Notably, we use AE signals acquired during heavy rain, which have generally been considered to be noise in the past. Analysis of rain-induced AE signals reveals severe cracks deep inside a deck, which would have been difficult to recognize by conventional passive non-destructive testing. Our method is also quite efficient with measurements able to be completed in a very short period of time.

1. Introduction

The deterioration of aging bridges and social infrastructures is a serious social issue. For example, within about 15 years, more than half of all bridges in Japan will be over 50 years old since their construction [1]. This suggests that the danger of serious accidents may increase in the future. To maintain all these bridges and maintain safety, it has become necessary to improve the efficiency of inspection and maintenance systems. From the viewpoint of efficient inspection, non-destructive testing (NDT) techniques provide a solution that does not require dismantling of the target, which would be costly, time-consuming, and sometimes impossible. Among the various kinds of efficient NDT techniques, passive monitoring is one of the most because it does not require human labor during the measurement. However, it can still be difficult to detect some kinds of damage inside structures by passive NDT techniques, such as horizontal cracks deep inside a bridge deck.

We have been developing a diagnostic method that uses an acoustic emission (AE) monitoring system as an efficient and effective NDT technique for bridge inspection. AE is an elastic wave generated by the fracturing of material. AE propagates through the material and can be detected by AE sensors, such as piezoelectric transducers. Diagnostic techniques using AE signal analysis have been widely investigated [2–8]. Various features of AE are used

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https://doi.org/10.1016/j.conbuildmat.2018.01.100
0950-0618/

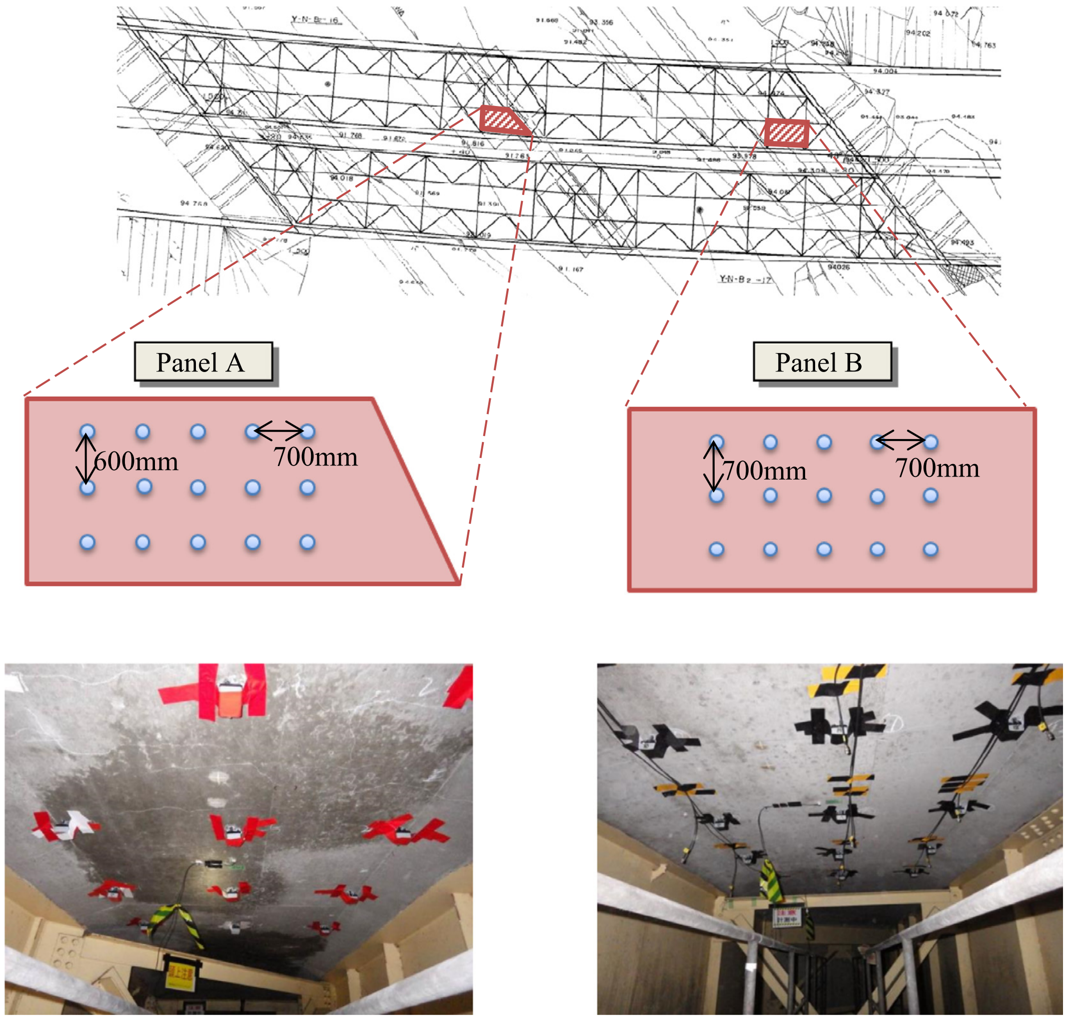

Fig. 1. AE sensor arrangement on bridge decks.

Table 1
Measurement parameters.

Frequency range of AE sensors	25 kHz – 80 kHz
Sampling rate	10 MHz
Threshold level	53 dB
Amplifier gain	46 dB
Rearm Time	0.2 ms

for analysis, including the activity of AE, the location of AE sources, analysis of AE waveforms, and wave velocity analysis by tomography techniques. We have developed a diagnostic method that uses a combination of the concentration of AE sources and the wave velocity structure derived from AE tomography [9]. We applied our method to a highway bridge while it was in service and successfully detected damage inside the RC bridge decks. In this experiment, AE activities caused by traffic load were acquired for about 1 week and analyzed precisely to derive the velocity distributions inside the bridge decks. This kind of precise and accurate diagnostic technique is important and useful. However, easier diagnostic techniques that can roughly but rapidly estimate the condition of a bridge are also valuable. We introduce another, easier diagnostic method in this paper.

The data acquired in the measurement above included a sudden increase in AE activities which were noise signals uncorrelated to traffic load. This noise seems to have been induced by heavy rain and should have been removed for accurate analysis. However, by analyzing the rain-induced signal, we identified large horizontal cracks deep inside the RC decks that would have been difficult to recognize by conventional passive NDT techniques. After our measurement, we have applied destructive testing to the measured decks and confirmed our analysis result.

2. Experiments

We installed AE sensors on the undersurface of the RC decks of an in-service highway bridge. Measurements were taken continuously over a period of about 1 week. The target bridge was constructed about 40 years earlier, and some of the decks of the bridge showed heavy deterioration due to the severe environment. The decks had been planned to be replaced due to this deterioration and they were actually removed after our experiment. Consequently, we were able to apply destructive testing to the measured decks to confirm our analysis results.

Fig. 1 shows the sensor arrangement on the bridge decks. The top part of the figure shows a top view of the bridge indicating two panels that were measured. Sensors were attached to each panel in a 3×5 configuration for a total of 30 sensors. The distances between adjacent sensors were 600 or 700 mm. Photos of the actual decks with AE sensors attached are shown in the bottom part of Fig. 1. Visual inspection found that panel A was more deteriorated than panel B, with indications of water leakage found on