Recommendation of RILEM TC 212-ACD: acoustic emission and related NDE techniques for crack detection and damage evaluation in concrete*

Test method for classification of active cracks in concrete structures by acoustic emission

RILEM Technical Committee (Masayasu Ohtsu)**

1 Scope

Concrete Structures are known to be no longer maintenance-free. Consequently, a variety of inspection techniques are under development and going to be established. It is well known that acoustic

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*The text presented hereafter is a draft for general consideration.

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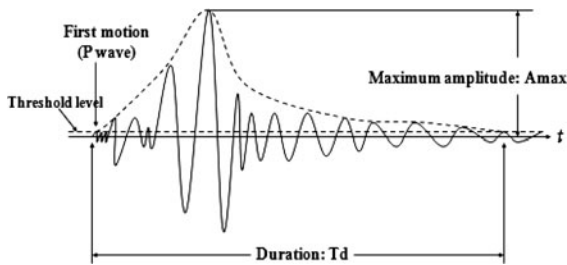e-mail: Ohtsu@gpo.kumamoto-u.ac.jp

emission (AE) technique is promising to test concrete structures for damage estimation [1]. For in-situ inspection, estimation of active cracks is of significant importance. Due to damage evolution in reinforced concrete structures, AE events are observed under in-service conditions. Generally speaking, nucleation of shear cracks follows tensile cracks on an existing failure surface. Accordingly, for an early warning of crack nucleation, the classification of active cracks is in great demand. In this recommendation, a classification criterion for micro-cracks in concrete is proposed on the basis of the measurement of AE parameters

The recommendation refers to several standards [2–12], of which the newest version shall be cited.

2 Definition of technical terms

In addition to terms defined in *RILEM recommendation*," Measurement Method for Acoustic Emission Signals in Concrete", the following AE parameters shall be obtained by the measurement system. AE waveform parameters of the following: peak amplitude, rise time and duration time are illustrated in Fig. 1, along with the threshold level.

(1) *Peak amplitude*: Largest amplitude value in a waveform.
(2) *Rise time*: A duration time from the first arrival to the peak amplitude.

Fig. 1 AE waveform parameters

(3) *Duration time*: Duration observed from the first arrival to the time when the amplitude decays up to the level lower than the threshold.

(4) *Counts*: Normally, AE counts imply number of times the signal amplitude exceeds the threshold. They also are rigorously named ring-down counts.

(5) *External parameters*: The measurement system shall be able to obtain time information along with AE parameters. In addition, such external parameters as load, strain and so forth are preferably recorded in the system.

3 Measurement system

3.1 AE sensor

AE sensors shall be calibrated properly in advance of the measurement. AE sensor is sensitive enough to detect AE signals generated in a concrete structure, taking acoustic coupling into consideration. AE sensor is also robust enough against temperature change, moisture condition and mechanical vibrations in the environments.

For the parameter analysis, a broad-band sensor is recommended. But, resonance-type sensors are also available, in the case that their resonance frequencies are higher than 60 kHz in concrete. So far, resonant frequencies of resonance-type sensors have been applied to concrete in the range of 50–250 kHz.

3.2 System for signal analysis

The system of AE devices shall be specified, depending on the target. AE sensors are attached at proper locations to cover the target area. The internal noise of the amplifier shall be inherently low and less than 20 μV (26 dB for 0 dB = 1 μV) as the peak voltage converted

by input voltage. The amplifier shall be robust enough against the environmental conditions and be protected properly. The frequency range shall be determined prior to the measurement, taking into account the performance of AE sensor and the amplifier. The range from several kHz to several 100 kHz is recommended in concrete. The period of the measurement shall be prescribed, depending on propagation property of AE signals in the target structure.

4 Environmental noises

In advance to AE measurement, the noise level shall be estimated. Then, counteract against external noises, wind, rain, sunshine and so forth shall be conducted to decrease the noise level as low as possible. In the case that the noises have similar frequency contents, amplitudes to AE signals or sources of the noises are unknown, characteristics of the noises shall be estimated prior to the measurement. Based on this result, separation of AE signals from the noises shall be achieved. In this respect, the use of filters is applicable after determining the proper frequency range.

Sensitivity of AE channels shall be conducted routinely by employing the standard source. Variation within the channels shall be less than 3%.

5 Test procedure

AE signals due to cracking shall be detected properly for the duration of the measurement. The test shall be conducted under loads which must not fundamentally make any critical damage on functions of the structure to detect and locate active cracks. In advance to the test, attenuation properties of the target structure shall be estimated, by employing the standard source or the equivalent.

From AE parameters of the rise time and the peak amplitude in Fig. 1, the RA value defined as,

$$\text{RA} = \text{the rise time/the peak amplitude} \qquad (1)$$

shall be calculated.

The averaged frequency Fa of each waveform shall be calculated from,

$$\text{Average frequency (Fa)} = \text{AE ringdown counts/} \\ \text{the duration time} \qquad (2)$$
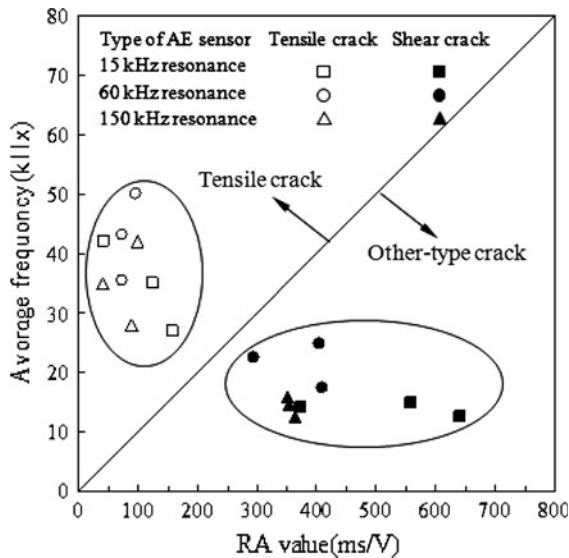
Fig. 2 Qualification of the damage by AE parameters

where the definitions of AE ring-down counts and the duration time are given in RILEM recommendation mentioned above.

By applying these parameters, classification of cracks into tensile cracks and other-type cracks including shear cracks is performed as shown in Fig. 2, where RA values and average frequencies plotted shall be calculated from the moving average of more than 50 hits. It is noted that the RA values may vary depending on the threshold level. But, the selection of AE sensors does not provide much effect on the results as shown in the figure.

For plotting data, the ordinate is shown by physical unit of kHz and the abscissa scale is msec/volt, where the amplitude shall be calibrated as the sensor output, compensating the effect of amplifiers. In the figure, the ratio of the abscissa scale to the ordinate scale is set to 10. But, it just means a suggestive value. A proper ratio shall be determined, depending on materials and structures. It is recommended to set the ratio in advance to the classification of active cracks. In a reference, it is recommended to apply the ratio of 50, based on the moment tensor analysis [13]. In another reference, just a trend of these two indices (1) and (2) is applied to identify the corrosion process in reinforced concrete [14], and to characterize the transition from tensile to shear cracking in steel-fiber reinforced concrete [15].

6 Documents

Documents to report the results shall contain the following articles:

(a) Date
(b) Test person
(c) Devices
(d) Measurement locations
(e) Results of system inspection before and after the setup
(f) Results

References

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