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Non-destructive testing — Acoustic emission testing — Test method for classification of active cracks in concrete structures

Essais non destructifs — Contrôle par émission acoustique — Méthode de test pour la classification des fissures actives dans les structures en béton

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 9, *Acoustic emission testing*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The number of aged concrete structures has been increasing all over the world. Since cracking is one major cause of damages in reinforced concrete (RC) structures, evaluation methods for crack distribution and cracking mechanisms are in great demand. To make a decision on maintenance and repair in concrete structures, non-destructive evaluation (NDE) techniques are often applied to estimate the safety and the performance of current state of concrete structures.

It is well known that acoustic emission (AE) technique is promising to test concrete structures for damage estimation. In this respect, a test method for classifying active cracks is established. Due to damage evolution in concrete structures in service, AE events are observed. Initially the tensile type of cracks in the microscopic scale is generated with short nucleation time. As approaching eventual failure, the shear type of cracks with long dislocation time is predominantly generated rather than the tensile type. Depending on these crack types, it is found that the shape of AE waveform changes. In frequency domain the tensile type has the higher frequency while the shear type has the lower frequency.

Thus, AE parameter-based method (parameter analysis) has been applied to crack classification. The proportion of the two AE parameters of the average frequency and the RA value is applied to classify cracks into tensile and shear cracks.

Non-destructive testing — Acoustic emission testing — Test method for classification of active cracks in concrete structures

1 Scope

This document specifies a test method for classification of active cracks in concrete structures.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12713, *Non-destructive testing — Acoustic emission inspection — Primary calibration of transducers*

ISO 12714, *Non-destructive testing — Acoustic emission inspection — Secondary calibration of acoustic emission sensors*

ISO 12716, *Non-destructive testing — Acoustic emission inspection — Vocabulary*

ISO/TR 13115, *Non-destructive testing — Methods for absolute calibration of acoustic emission transducers by the reciprocity technique*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12716 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
RA value
reciprocal of a wave gradient, obtaining the rise time divided by the peak amplitude

3.2
average frequency
F_a
apparent frequency, obtained as counts divided by the duration time

4 Measurement system

4.1 AE sensor

AE sensors shall be calibrated properly in advance of the measurement in accordance with ISO 12713, ISO 12714 and ISO/TR 13115. AE sensors shall be sensitive enough to detect AE signals generated in a concrete structure, taking acoustic coupling into consideration. AE sensor shall also be 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.

4.2 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_{AE} for 0 dB_{AE} = 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 duration of the measurement shall be prescribed, depending on the propagation property of AE signals in the target structure.

5 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, while 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.

The sensitivity of AE channels shall be checked routinely by employing the standard source. The variation within the channels shall be less than ±3 dB_{AE}.

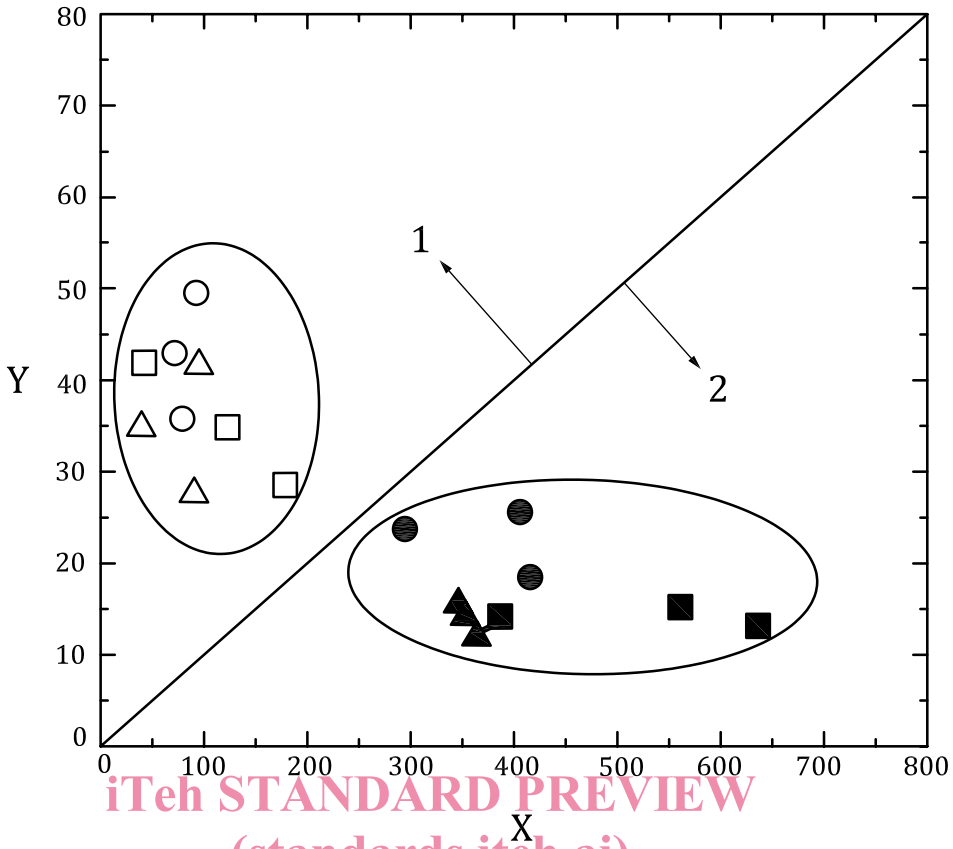
6 Test procedure

AE signals due to cracking shall be detected properly for the duration of the measurement. The test shall be conducted under loads which shall 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.

AE measurement is conducted in accordance with ISO 16836 and AE data is recorded with conventional AE parameters. RA values as well as average frequency are calculated based on the definition described in 3.1.

By applying these parameters, classification of cracks into tensile cracks and other-types of cracks including shear cracks is performed as shown in Figure 1. It is noted that the RA values may vary depending on the threshold level; but the figure shows that the selection of AE sensors does not provide much effect on the results as shown in the figure.

For plotting data, here, 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 consideration of the threshold, attenuation rate and the propagation distances.



Key

X RA values (ms/V)

Y average frequency (kHz)

1 tensile cracks

2 other type of cracks

○ AE sensors of 60 kHz resonant frenquency, cracks

□ AE sensors of 15 kHz resonant frenquency, cracks

△ AE sensors of 150 kHz resonant frenquency, cracks

● AE sensors of 60 kHz resonant frenquency, classified

■ AE sensors of 15 kHz resonant frenquency, classified

▲ AE sensors of 150 kHz resonant frenquency, classified

Figure 1 — Qualification of the damage by AE parameters

7 Test report

Documents to report the results shall contain the following:

a) the date;

b) the test person;

c) the devices;

d) the locations of measurement;

e) the results of system inspection before and after the setup;