INTERNATIONAL STANDARD

ISO 16836

First edition
2019-01

Non-destructive testing — Acoustic emission testing — Measurement method for acoustic emission signals in concrete

Essais non destructifs — Contrôle par émission acoustique — Méthode de mesure pour les signaux d'émission acoustique dans le béton

Reference number
ISO 16836:2019(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

Acoustic emission (AE) techniques have been investigated in concrete engineering for more than a half century. Nowadays, results of AE research are put to practical use for infrastructures, not only concrete structures, but also masonry structures.

Concrete structures can deteriorate due to heavy traffic loads, fatigue, chemical reactions and unpredictable disasters, although concrete structures have long been referred to as maintenance-free. Eventually, retrofit and rehabilitation of the structures are in heavy demand all over the world. It results in the need for the development of advanced and effective inspection techniques prior to repair work. In this regard, AE techniques have been extensively studied in concrete engineering.

Focusing on crack detection and damage evaluation, it is known that AE techniques are prospectively applicable to concrete and concrete structures. Therefore, basic aspects on the measurement method for AE signals in concrete are prescribed. AE is an inspection technique, by which elastic waves due to cracking and damage in concrete are detected. Since AE phenomena are to be observed under in-service conditions, AE measurement can be conducted not only in a laboratory, but also on site.

Non-destructive testing — Acoustic emission testing — Measurement method for acoustic emission signals in concrete

1 Scope

This document establishes a measurement method for acoustic emission signals in concrete.

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
acoustic emission
AE
transient elastic waves generated by the release of energy within a material

3.2
AE signal
electrical signal detected at a sensor, which is converted through the detection of *AE wave* (3.3) (elastic wave)

3.3
AE wave
wave that can be detected in the form of *hits* (3.5) on one or more *channels* (3.4)

3.4
channel
one line of *AE signal* (3.2) detected by *AE* (3.1) sensor and processed by the other devices

3.5
hit
given *AE* (3.1) *channel* (3.4) that has detected and processed one AE transient

3.6
event
group of *AE* (3.1) *hits* (3.5) received from a single source by two or more *channels* (3.4), of which spatial coordinates can be located

3.7
array
spatial arrangement of *AE* (3.1) sensors for spatially locating AE sources

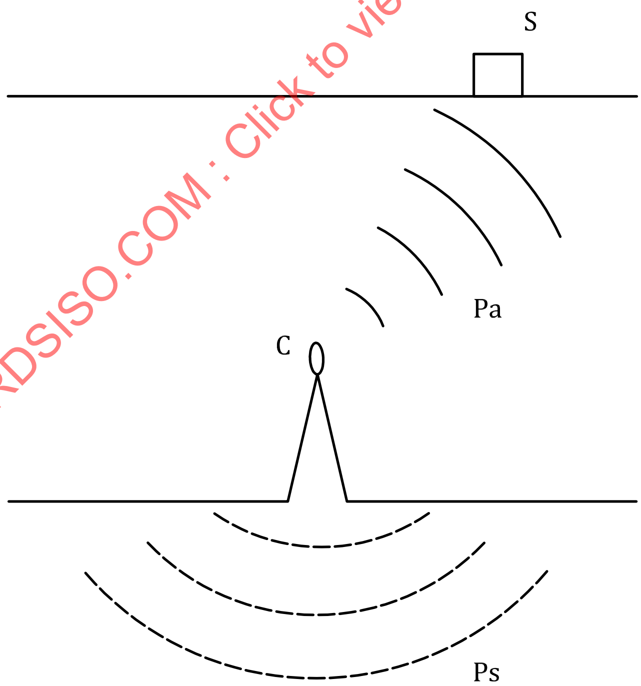
3.8
attenuation
observed loss of a signal as it travels through a medium

3.9
noise
signal produced by causes other than *AE* (3.1) phenomena

Note 1 to entry: Elimination of noises is essential for effective detection of *AE signals* (3.2).

4 Detection of AE waves

Microscopic fracture in concrete takes place with the release of stored strain energy as nucleating micro-cracks and generating elastic waves. These waves due to crack nucleation are referred to as AE waves, which propagate inside a material and are detected by an AE sensor as shown in Figure 1.



Key

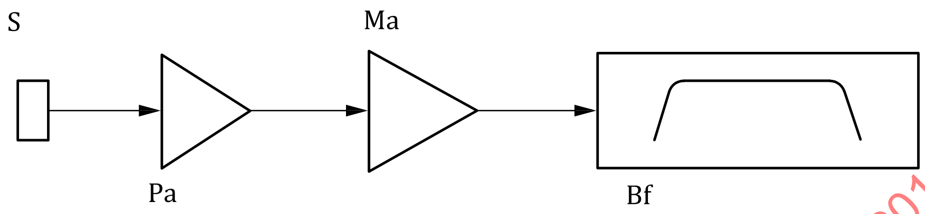
S detection of AE waves by an AE sensor
Pa propagation of AE waves
C nucleation of a crack
Ps propagation of sound waves in air

Figure 1 — Detection of AE waves

5 Measuring system

5.1 General

A basic system is illustrated in Figure 2, where only analog devices are shown. Following this system, a digital signal-processor is usually applied.



Key

S AE sensor

Pa pre-amplifier

Ma main amplifier

Bf band-pass filter

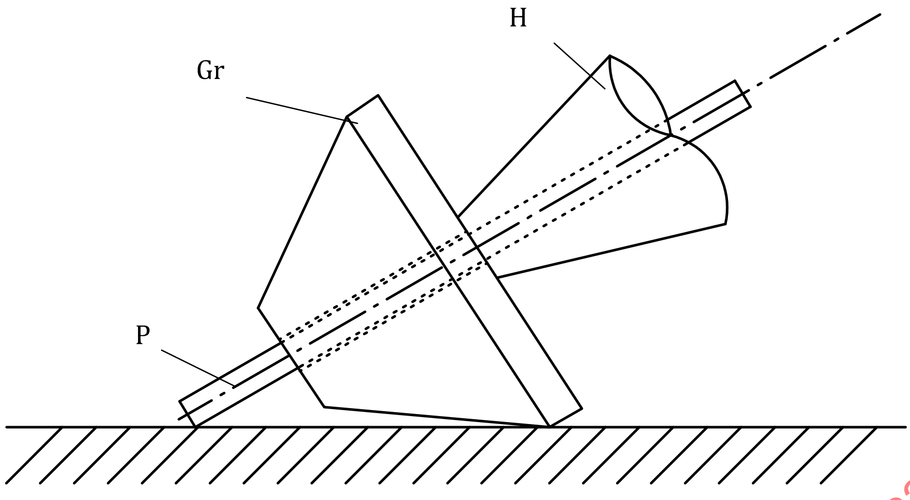
Figure 2 — AE measurement system

5.2 Sensor

AE sensors shall be sensitive enough to detect AE signals generated in the target structure, taking acoustic coupling into consideration. They convert elastic waves (motions) on the surface of a material into electric signals, preferably, without any distortions. A resonance-type sensor is most sensitive around the resonant frequency, while a broad-band sensor has approximately flat response in the range but is less sensitive than the resonance-type. AE sensor shall be robust enough against temperature change, moisture condition and mechanical vibrations in the environments.

Refer to Annex A for recommended types of sensors to be used in the concrete.

Sensitivity calibration of AE sensors shall be performed by employing the standard source, in addition to the calibration methods prescribed in ISO 12713 and ISO 12714. A simulated AE source due to pencil-lead break is defined in ASTM E976. This standard source is illustrated in Figure 3, where a guide ring is recommended to be employed.



Key

H lead-holder of a mechanical pencil

Gr guid ring of Teflon

P pencil lead of 0,5 mm diameter and 3 mm length

Figure 3 — Standard AE source

Absolute calibration of AE sensors shall be made on the basis of ISO/TR 13115.

5.3 Amplifier

Amplifiers normally consist of the pre-amplifier and the main amplifier as shown in Figure 2. The pre-amplifier shall be located as close as possible to AE sensor. 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. Here, the gain of the amplifier is given in dB_{AE} (decibels AE), which means the ratio of the output voltage V_0 to the input voltage V_i as;

$$\mathrm{dB}_{\mathrm{AE}} = 20\log\left(\frac{V_0}{V_\mathrm{i}}\right)$$

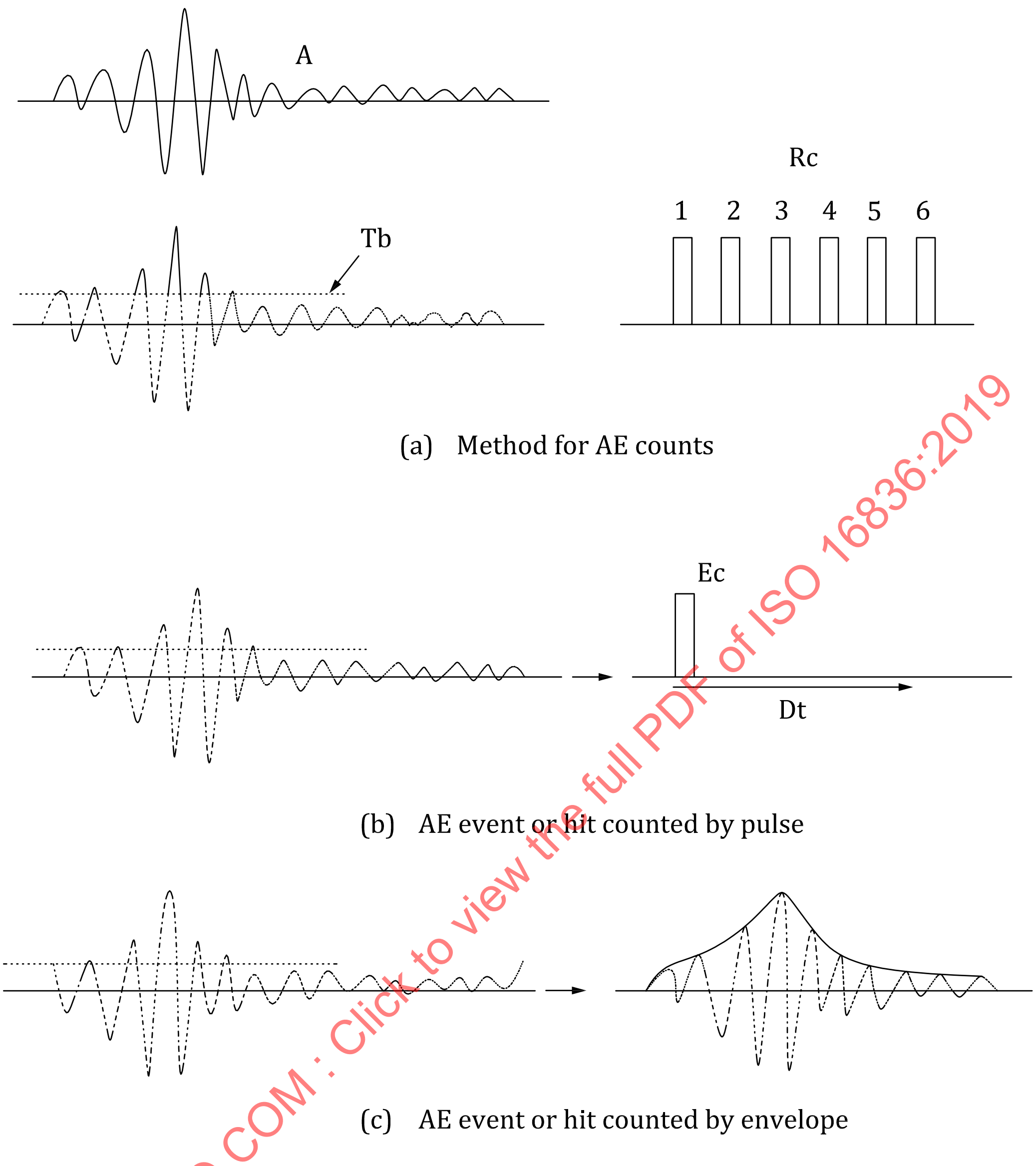
The amplifier shall be robust enough against the environmental conditions and be protected properly.

5.4 Filter

The frequency range shall be determined prior to the measurement, taking into account the performance of AE sensors and the amplifiers. Selection of the frequency rage is closely related to elimination of noises. In concrete, the use of a band-pass filter between several kHz and several 100 kHz is recommended.

6 Signal analysis and AE parameters

One waveform is to be counted as one AE event, while the cycles over the threshold level are named as AE ring-down counts (or simply “counts”). Here, the threshold is a preset voltage level, which has to be exceeded before one AE signal is detected and processed. Methods for AE counting are illustrated in Figure 4. In the case of multi-channel observation, AE occurrence is monitored at each sensor location. At some sensors, AE signals may not be observed due to attenuation or undetectable propagation path. The number of the events which are counted at one of the channels corresponds to the number of AE hits defined above.



Key

A AE waveform

Th threshold

Rc ring-down counting

Ec event counting

Dt dead time

Figure 4 — AE counting methods

In addition to AE count, AE hit and AE event, the following AE parameters shall be obtained by the measurement system:

a) peak amplitude;

b) AE energy;

c) rise time;

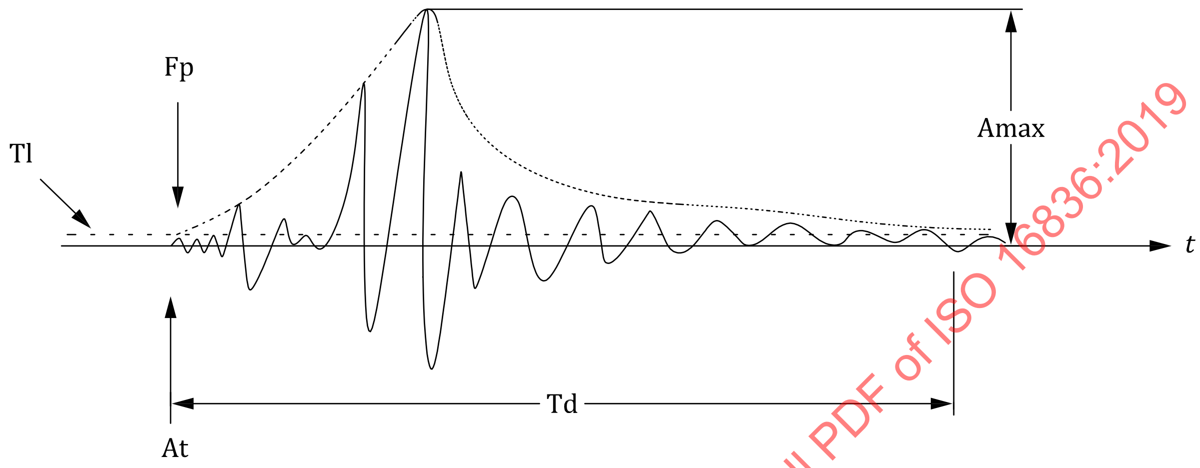
d) duration;

e) arrival time differences in AE sensor array;

f) 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.

The waveform parameters of arrival time, duration and peak amplitude are displayed in Figure 5, showing the threshold level. The rise time means a duration from the arrival to the peak. There exist a variety of definitions on AE energy. In principle, AE energy corresponds to an area of the envelope of the waveform.



Key

Tl threshold level

Fp first motion of P wave

At arrival time

Td duration

Amax maximum amplitude

t time

Figure 5 — AE waveform parameters

7 Setup and measurement

7.1 Sensor setup

AE sensors shall be calibrated properly in advance of the measurement. They are attached at proper locations to cover the target area. The number of AE sensors and the period of the measurement shall be prescribed depending on the following conditions:

a) propagation property of AE signals in the target structure;

b) stress distribution in the structure under inspection.

7.2 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.

