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Standard Guide for Acoustic Emission Examination of Concrete Structures[1]

This standard is issued under the fixed designation E3100; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide describes the application of acoustic emission (AE) technology for examination of concrete and reinforced concrete structures during or after construction, or in service.

1.2 Structures under consideration include but are not limited to buildings, bridges, hydraulic structures, tunnels, decks, pre/post-tensioned (PT) structures, piers, nuclear containment units, storage tanks, and associated structural elements.

1.3 AE examinations may be conducted periodically (short-term) or monitored continuously (long-term), under normal service conditions or under specially designed loading procedures. Examples of typical examinations are the detection of growing cracks in structures or their elements under normal service conditions or during controlled load testing, long term monitoring of pre-stressed cables, and establishing safe operational loads.

1.4 AE examination results are achieved through detection, location, and characterization of active AE sources within concrete and reinforced concrete. Such sources include micro- and macro-crack development in concrete due to loading scenarios such as fatigue, overload, settlement, impact, seismicity, fire and explosion, and also environmental effects such as temperature gradients and internal or external chemical attack (such as sulfate attack and alkali-silica reaction) or radiation. Other AE source mechanisms include corrosion of rebar or other metal parts, corrosion and rupture of cables in pre-stressed concrete, as well as friction due to structural movement or instability, or both.

1.5 This guide discusses selection of the AE apparatus, setup, system performance verification, detection and processing of concrete damage related AE activity. The guide also provides approaches that may be used in analysis and interpretation of acoustic emission data, assessment of examination results and establishing accept/reject criteria.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

E1932 Guide for Acoustic Emission Examination of Small Parts

E2374 Guide for Acoustic Emission System Performance Verification

2.2 *ANSI/ASNT Standards:*[3]

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel

[1] This test method is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.04 on Acoustic Emission Method.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

2.3 *AIA Standard*[4]

NAS-410 Certification and Qualification of Nondestructive Personnel (Quality Assurance Committee)

2.4 *ISO Standard:*[5]

ISO 9712 Non-Destructive Testing-Qualification and Certification of NDT Personnel

2.5 *American Concrete Institute Documents*[6]

ACI 228.2R-13 Report on Nondestructive Test Methods for Evaluation of Concrete in Structures

ACI 228.1R-03 In-Place Methods to Estimate Concrete Strength

ACI 437R-03 Strength Evaluation of Existing Concrete Buildings

3. Terminology

3.1 *Definitions*—See E1316 for terminology related to this guide.

4. Summary of Guide

4.1 The guide describes the process of AE examination of concrete structures and discusses selection of the AE apparatus, setup, system performance verification, detection and processing of concrete damage related signals.

5. Significance and Use

5.1 Real-time detection and assessment of cracks and other flaws in concrete structures is of great importance. A number of methods have been developed and standardized in recent decades for non-destructive evaluation of concrete structures as well as methods for in-place evaluation of concrete properties. Review of some of these methods can be found in ACI 228.2R-13, ACI 228.1R-03, and ACI 437R-03. They include visual inspection, stress-wave methods such as impact echo, pulse velocity, impulse response, nuclear methods, active and passive infrared thermography, ground-penetrating radar and others. These methods in most of the cases are not used for overall inspection of the concrete structure due to limited accessibility, significant thickness of concrete components, or other reasons and are not applied for continuous long-term monitoring. Further, these methods cannot be utilized for estimation of flaw propagation rate or evaluation of flaw sensitivity to operational level loads or environmental changes, or both.

5.2 In addition to the previously mentioned non-destructive tests methods, vibration, displacement, tilt, shock, strain monitoring, and other methods have been applied to monitor, periodically or continuously, various factors that can affect the integrity of concrete structures during operation. However, these methods monitor risk factors that are not necessarily associated with actual damage accumulation in the monitored structures.

5.3 Monitoring the horizontal (opening) or vertical displacement of existing cracks can be performed as well using different technologies. These may include moving scales (Fig. 1), vibrating wire, draw wire, or other crack opening displacement meters, optical and digital microscopes, strain gages, or visual assessment. However, this type of monitoring is only applicable to surface cracks and requires long monitoring periods.

5.4 This guide is meant to be used for development of acoustic emission applications related to examination and monitoring of concrete and reinforced concrete structures.

[4] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aiaaerospace.org.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

[6] Available from American Concrete Institute (ACI), 38800 Country Club Dr., Farmington Hills, MI 48331-3439, http://www.concrete.org.

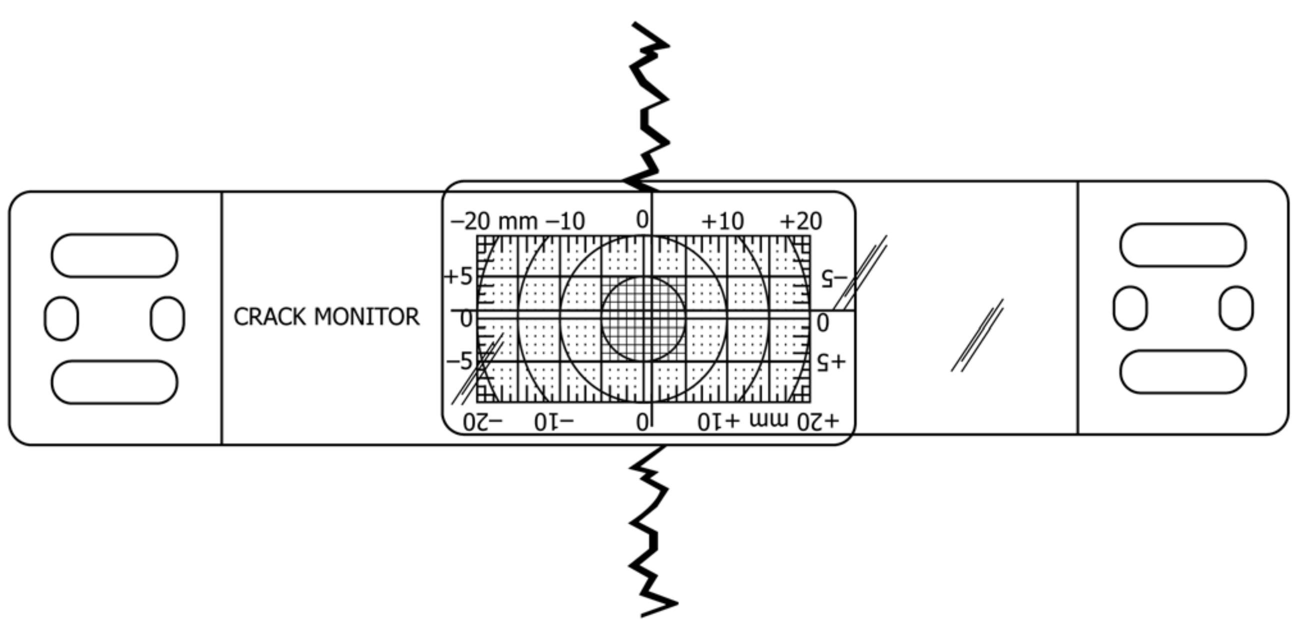

FIG. 1 Moving Scale Crack Opening Monitor

5.5 Acoustic emission technology can provide additional information regarding condition of concrete structures compared to the methods described in sections 5.1 – 5.3. For example, the acoustic emission method can be used to detect and monitor internal cracks growing in the concrete, assess crack growth rate as a function of different load or environmental conditions, or to detect concrete micro-cracking due to significant rebar corrosion.

5.6 Accuracy, robustness, and efficiency of AE procedures can be enhanced through the implementation of fundamental principles described in the guide.

6. Basis of Application

6.1 The following items are subject to contractual agreement between the parties using or referencing this guide.

6.2 *Personnel Qualification:*

6.2.1 If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally and internationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT CP-189, SNT-TC-1A, NAS-410, ISO 9712, or a similar document and certified by the employer or certifying agency, as applicable. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

6.3 *Qualification of Nondestructive Testing Agencies:*

6.3.1 If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E543. The applicable edition of Practice E543 shall be specified in the contractual agreement.

7. The Process of Acoustic Emission Examination of Concrete Structures

7.1 The process of AE examination of concrete structures includes the following principal steps. As decisions are made under these steps (7.1.1 – 7.1.4), a test procedure or instruction shall be written, based on those steps, to guide the field activities.

7.1.1 Defining the goal(s) of the examination.

7.1.2 Developing an understanding of the structural system, material properties, and flaw characteristics.

7.1.3 Selection of the operational, load, and environmental conditions for conducting the examination.

7.1.4 Selection of suitable equipment and sensor installation methods.

7.1.5 System performance verification.

7.1.6 Field examination and post examination system performance verification.

7.1.7 Data analysis, interpretation, and assessment.

7.1.8 Reporting.

8. Defining Goals of the Examination

8.1 Prior to conducting an AE examination or AE structural health monitoring of a concrete structure, it is necessary to define the primary goals and the scope of the examination together with a designer or operator of the structure, or both (**1**).[7] Success of the examination is defined as the degree to which the goals of the examination is achieved.

8.2 The way in which AE technology is applied can vary with different goals. Examples of primary goals are:

8.2.1 Evaluation of known crack development under specific load conditions.

8.2.2 Characterization of mechanical and fracture mechanics properties of concrete members used in a structure.

8.2.3 Establishment of safe loads/operational conditions.

8.2.4 Prediction of ultimate loads.

8.3 Primary examination goals can be achieved when at least one or several of the following objectives are addressed:

8.3.1 Detection of active concrete cracking and other flaw-indications in the structure.

8.3.2 Location of flaw-indications.

8.3.3 Identification of flaw-indications, for example, identification of tensile or shear concrete micro-cracking, corrosion damage, and others (**2-4**).

8.3.4 Assessment of flaw-indications, for example damage qualification of reinforced concrete beams subjected to repeated loading (**3**).

8.3.5 Structural integrity diagnostics and establishment of serviceability.

8.3.6 Prediction of ultimate loads.

9. Understanding the Structure, Material Properties, and Flaw Characteristics

9.1 Correct interpretation of AE results for source mechanism identification, flaw-indication assessment and diagnostics depends on satisfactory knowledge of the examined structure, examination conditions (including environmental), understanding the material properties of the structure, manufacturing methods and material behavior under stress. Therefore, prior to an acoustic emission examination, it is recommended to obtain the following information:

9.1.1 *Structural Information:*

9.1.1.1 The function of the structure and its design including detailed drawings, if available.

9.1.1.2 Operational/stress/environmental conditions and other factors that may contribute to flaw origination and development.

9.1.1.3 Results of previous NDT examinations, including the location and nature of known flaw indications (if any).

9.1.1.4 Statistics of failures of similar structures, typical flaws, possible location of flaws and expected rate of flaw propagation.

9.1.1.5 Factors that can contribute to flaw origination and development (deformation, support instability, known or suspected design errors, etc.).

9.1.1.6 Wave propagation characteristics in the structure (propagation modes, velocities, attenuation characteristics, effects of anisotropy, etc.).

9.1.2 *Material Information:*

[7] The boldface numbers in parentheses refer to a list of references at the end of this standard.