Construction and Building Materials 65 (2014) 282–302

Contents lists available at ScienceDirect

Construction and Building Materials

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

Review

Advanced structural health monitoring of concrete structures with the aid of acoustic emission

Arash Behnia [a], Hwa Kian Chai [a,*], Tomoki Shiotani [b]

[a] Civil Engineering Department, University of Malaya, Kuala Lumpur 50603, Malaysia
[b] Dept. of Urban Management, Graduate School of Engineering, Kyoto University, Kyoto, Japan

HIGHLIGHTS

- The latest developments in the field of structural health monitoring by means of AE.
- The latest available evaluation parameters to assess the severity and type of damages by means of AE.
- The most suitable practical methods to monitor concrete structure in different types of damages by means of AE.
- Introducing available quantitative and qualitative AE methods to monitor concrete structures.
- Introducing the current limits of acoustic application and novel on-going researches to come up with practical solutions.

ARTICLE INFO

Article history:
Received 11 March 2014
Received in revised form 14 April 2014
Accepted 17 April 2014
Available online 22 May 2014

Keywords:
Acoustic emission technique
Concrete structures assessment
Damage detection
Structural health monitoring

ABSTRACT

This article gives a comprehensive review of the acoustic emission (AE) technique for its applications in concrete structure health monitoring. Basic and established condition assessment methods for concrete structures are reviewed to configure a firm perception of AE application for enhanced performance and reliability. The AE approaches of focus are the parametric and signal analysis which can be used to develop damage evaluation criteria. Other than recent localization and source discrimination methods, applications of pivotal AE parameters such as *b*-value, *Ib*-value, AE energy, and hit are discussed herein, with highlights on the limitation of the individual parameter-based approaches when adopted on site. In addition, the introduction of new parameters such as sifted *b*-value, minimum *b*-value, and *Q* value is discussed as well, followed by a novel recent strategy for AE application in conjunction with tomography method to facilitate infrastructure assessment. Moreover, the key role of application of artificial intelligence methods towards damage mode identification has been highlighted.

Contents

* Corresponding author. Tel.: +60 185793885.
E-mail address: hkchai@um.edu.my (H.K. Chai).

http://dx.doi.org/10.1016/j.conbuildmat.2014.04.103
0950-0618/

1. Introduction

The phenomenon of acoustic emission is defined as the propagation of elastic waves due to the release of localized internal energy, such as a micro-fracture in elastic material [1–5]. Sources of AE activities include structural deformation processes as plastic deformation, crack expansion and other kinds of material degradation. The AE process involves the use of sensors to detect released strain energy generated from growing cracks [6,7].

AE technique has been widely used in the field of civil engineering for structural health monitoring (SHM) [5,8–11]. The advantages of using AE technique compared to other nondestructive techniques are that the position of the developing cracks can be determined and the entire structure can be tested without interrupting the performance of the structure. Classification and crack direction can be calculated through different approaches such as *b*-value analysis of AE [12–17].

AE activities are categorized in two groups namely 'primary AE activity' and 'secondary AE activity'. The former considers crack growth or crack formation while in the latter crack growth has been stopped and the intended activity is based on friction between crack surfaces. Two typical crack modes should be considered when investigating the cracking behavior in structures with AE parameters since the fracture cracking mode in concrete structure changes as the fracture progresses from the tensile type (mode I) to the shear type (mode II). Usually AE activities pertinent to mode I type cracks are registered when the fracture growth is in the stable stage. Upon reaching final failure, most recorded AE activities are related to mode II type cracks.

On the other hand, in loading and unloading system, during unloading process in the early stages, few AE events are expected. Approaching final failure, during the unloading process AE activities would be considerably increased. Therefore AE activity during unloading process has potential to show the damage degree. As a result, different aspects of structural defect including damage intensity, crack mode and health level of the structure is measurable using parameters extracted from AE signals.

2. Potential structural assessment approaches based on AE and motivations of this study

AE technique is extensively used for real-time damage monitoring. The premise of AE refers to the generation of transient elastic waves during the rapid release of energy from a localized source within a material. The fundamental concept of AE brings some unique features for this technique as an applicable non-destructive testing technique. Among these features the most important ones are (1) real time capability, (2) high sensitivity, (3) global monitoring capability, (4) source location, (5) sensitivity to any process or mechanism that generates stress waves, (6) passive nature (no need to supply energy from outside, but energy from damage source itself is utilized). Considering AE features, the application of AE might be divided in two core categories; (1) global structural health monitoring which can provide total insight into the situation of the structure and focuses on overall health of structure, for example, analysis of AE parameters or waveform may result into a general perception of damage severity or identification of the nature of damage through entire dataset of all sensor arrays;