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Damage Assessment using Acoustic Emission on Concrete Beam

Sakhiah Abdul Kudus, Adiza Jamadin, Norliyati Mohd Amin, Nurul Huda Suliman, Anizahyati Alisibramulisi

Abstract: ***The selection of reliable technique for damage assessment is important in civil engineering structure. The present study proposed Acoustic emission (AE) technique by using the fundamental AE parameter to evaluate damage accumulated on Ultra High-Performance Concrete (UHPC) specimens. The UHPC beam with dimension of 515 mm x 98 mm x 98 mm was tested under three-point bending test with stepwise flexural load. In order to detect and to collect the AE data, Micro-SAMOS (µ-SAMOS) digital AE system and R6I sensors type were used while data analyses were carried out using AEwin software. The damage level that take place during increasing static loading on tested concrete beams and the mechanism was successfully evaluated using the AE technique.***

Keywords **:** ***Acoustic emission, damage assessment, concrete.***

I. INTRODUCTION

The demand on non-destructive technique (NDT) for assessment of structural reliability is nowadays increase associated to increase of demand on worldwide concrete. The corrosion of reinforcing steel and consequently the cracking of the surrounding concrete is the most serious and costly form of damage to the concrete structure. Thus, a reliable technique of testing of building and follow up of civil engineering structure is significant in order to guarantee the safety of user.

NDT are described as techniques used to determine the integrity of a material which can be divided into two major group, passive and active methods. Passive method relies on source from the monitored specimen itself, whereas in active method external sources was given to the monitored specimen. Both active and passive NDT allow the assessment conducted without stress or destroying and causing harm to the tested object.

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***** Correspondence Author
Sakhiah Abdul Kudus*, Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia, sakhiah@uitm.edu.my.
Adiza Jamadin, Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia, adiza@salam.uitm.edu.my.
Norliyati Mohd Amin, Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia, norli830@salam.uitm.edu.my
Anizahyati Alisibramulisi, Institute for Infrastructure Engineering and Sustainable (IIESM), UiTM, Shah Alam, Malaysia, aniza659@salam.uitm.edu.my
Nurul Huda Suliman, Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia, nurul_huda@salam.uitm.edu.my

NDT is one part of structural health monitoring where generally in SHM basic fundamental dynamic characteristics of structure including fundamental modal parameters were used to understand development of damage on monitored structure [1,2,3,4]. This technique provide user the global response of the structure whereas AE technique generally used for localize damage assessment [5]. Each of the NDT method has its own benefits and disadvantages depending on the materials and conditions of the tested specimens or structures.

The mechanism of monitoring by AE technique utilize the wave signal generated from the structure, which might happen from the propagation of crack under stress, to parameterize the process of failure, together with the secondary emissions due to friction of crack interfaces. The of AE technique give provide advantage to the user as AE is capable to conduct real time damage process mapping which distinguishes this technique from other nondestructive testing methods. With the capability, the information of real time source location can be obtained from the captured AE events. The indication of the degree of damage captured can referred to the level of energy and magnitude of the detected events, where the surrounding sources of noises are eliminated [6].

The AE technique provide the user with its practicality for global monitoring where the structure categorized as complex and large possible to be monitored bu using limited number of sensors. Therefore, the entire structure with most sensitive region can be aimed with a more thorough AE monitoring for assessment and quantification using AE parameters [7].

Proverbio et al., (2009) used the b-value analysis has been to evaluate damage condition of concrete structure and this analysis has been successfully applied in evaluating the different stages of damage occurring in concrete structures under loading that had been applied. In addition, Proverbio et al., (2009) also used the Ib-value analysis to analyse the damage conditions of concrete structure. The latter analysis showed a promising result and possible to be use to differentiate the degrees of damage in concrete structures [8].

The tested specimen, ultra-high performance concrete (UHPC) is the among the current development in concrete technology strengthen by hooked steel fibers. From literature, UHPC is describe as a type of concrete have very brittle failure characteristics and the elements fail explosively without any omen [9]. The work presented here focuses on the applicability of the AE technique in order to evaluate damage accumulation in structure subjected to increasing static loading. The tensile mode and shear mode take place during the fracture are also discussed.

The AEwin processor is use to obtain the data and the is analyse and discuss. From the result of this study, the location of the tensile and shear mode develops on the structure during the testing has been identified.

II. PROCEDURE FOR PAPER SUBMISSION

The acoustic emission instrumentation comprises of transducers (sensors), pre-amplifiers, amplifiers, filters, and software analysis which is AEwin. Throughout the experiment, the micro – SAMOS (μ - SAMOS) hardware from Physical Acoustic Corporation is used. In this study, sensor type of R6I with an operating frequency range of 40-100 kHz was used.

The specimen was placed 50mm from the support as shown in Fig. 1. The point load was on the center of the specimen. Complete instrument setup is indicated in Fig. 2. Before proceed with any AE monitoring, all the sensors used need to be ensured correctly mounted and couplants is used on surface of sensor. Improper mounting of the sensor might result in decreasing of sensitivity and might cause loss of important AE data. Testing of the sensor sensitivity conducted using the Hsu-Nielson source with 2H pencil lead. This is confirmed according to American Society for Testing and Materials (ASTM) E976 (2007) [10]. The amplitude's range for sensitivities is about 90-100 dB. The Teflon guide ring is used to prevent false signals and that it is possible to reproduce a similar emission continuously and to ensure the signal from braking position is stable.

In present study, 1000 MSPS (Mega samples per second) sampling rate was set and 250.00 μs is the pre trigger setting. Wave velocity was 3500 m/s. This represent the longitudinal wave in concrete specimen. This setting is important prior to testing in order to obtain correct location of the released emission. The testing was carried out with simultaneously monitored by using AE technique. The displacement was set constant at rate of 0.1 mm/min during the test and it was carried out continuously until failure.

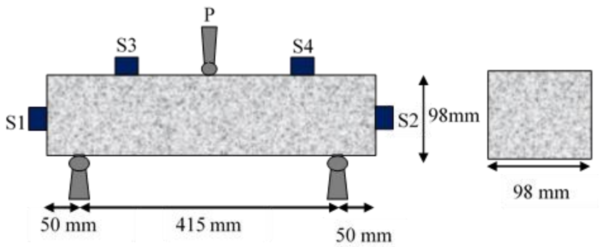

Fig. 1: The position of sensors.

Fig. 2: The complete setup of the instruments.

III. RESULT AND DISCUSSION

The level of damage accumulated in a structure is associated with the loads imposed which caused the cracks development. In AE, the signals that relate the frequency and amplitude were generated from different types of cracks by means of AE [11], in which the micro-cracks produce a higher number of events of small amplitude while macro-cracks generate fewer events but with bigger amplitude. This is related to the energy released during the opening of crack and therefore higher number of events are created with low amplitude [11].

In this study, the data analysis from the AEwin software is explained according to the location and activity of the AE system as indicated in Fig. 3 and Fig. 4. The graph shows where the emission is coming from. The capability of the AEwin system to detect the damage from the cracking is measured. Activity displays show AE activity as a function of time in the graph. This display is important to obtained the total emission number and the average rate of emission [12]. Location display is a graph with position or channel linearly.

At the earlier stage of the test, the AE parameter value was increased in small amplitude. This implies the formation of weak regions and the initiation of flaws which was present in the first stage of loading. The cumulative values of AE parameter increased dramatically during the unstable cracking stage leads to failure process of the specimens.

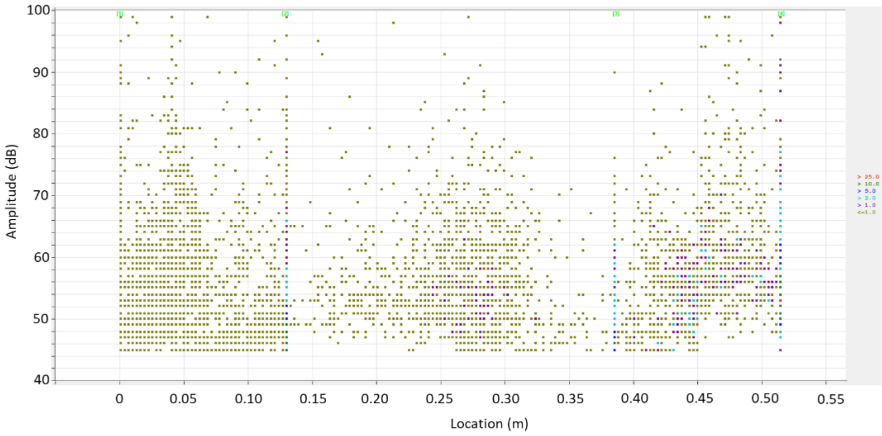

Fig. 3: Event location based on amplitude.

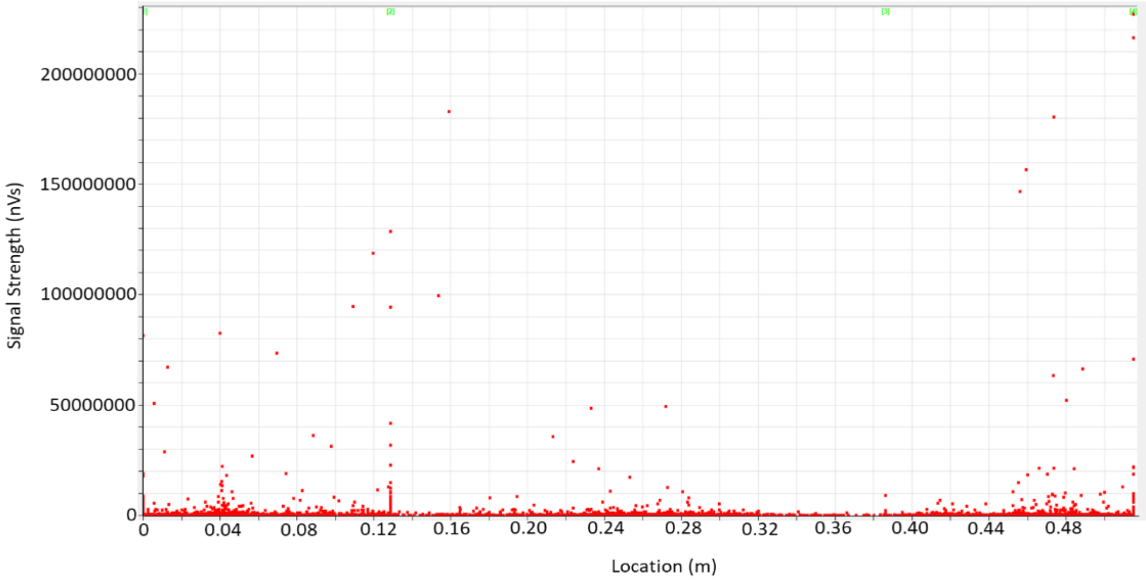

Fig. 4: Event location based on signal strength

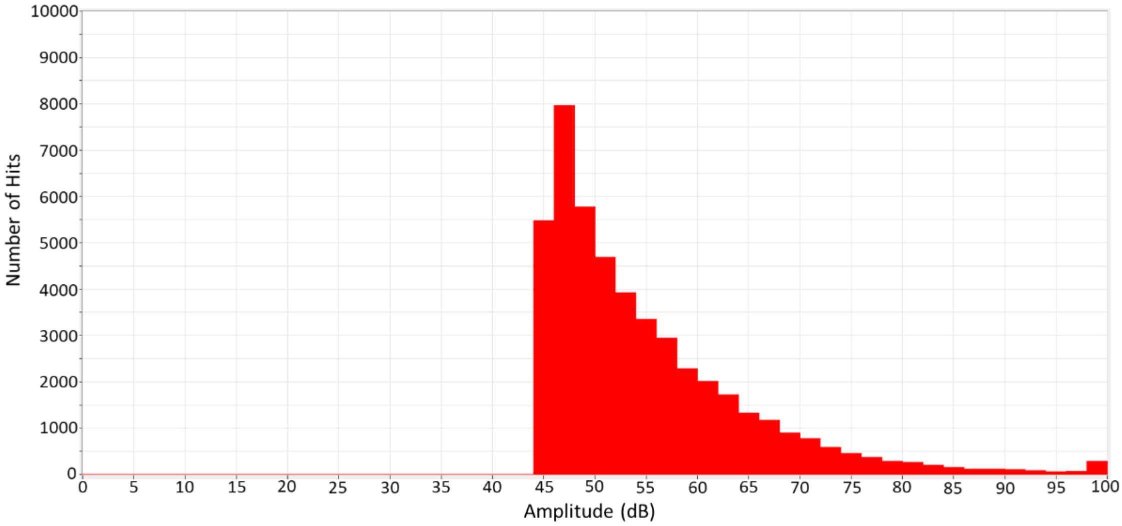

Fig. 5: Number of AE Hits over the amplitude (dB)

The number of AE event captured is less at the beginning of the testing because at this stage only involve with development of microcracks. As the loading is increased, a surface-breaking and crack propagate, the structure tends to opens up due to the applied forces. This is far more serious than the opening of an inclusion, which would tend to have no more than a local effect. Due to this event, the cracks tend to produce greater amplitude signals that are more readily significant.

Furthermore, the commencement and propagation of crack in concrete is generally related to the AE waves obtained which have several peak amplitudes [13].

There are two types of crack take place during the increase of load on the specimen. Table 1 detailed the AE signal features behavior for shear and tensile crack [14]. Fig. 6 and Fig. 7 further explain the AE event for both shear and tensile mode developed in this test.

It was observed that the tensile mode take place first from the visual observation followed with shear mode. The shear crack was developed and propagate towards the support. It is clear in Fig. 3 where the dominant AE event is in the middle of the beam and above support area. In the last stage of failure mechanism, the higher increment of AE hits was due to the development of unstable rapid propagation of macro-cracks which led to failure.

Table 1: Features of AE signal obtained due to propagation of crack under bending test [14].

AE signal features	Tensile mode	Shear mode
AE Waveform-length	Short	Long
Rise time (RT)	Short	Long
RA value	Reduced	Increased
Average frequency	Increased	Reduced
Quantity of realized energy	Lesser	Higher
Speed of realized energy	More rapid	Less rapid

Several factors related to AE process need to be emphasized in order to obtain meaningful AE monitoring. Merely place the AE sensors to the structure and capturing the data is insufficient. The process begins from the arrangement of sensor on the monitored structure. The attention also should be given to the type of analysis suitable for the aimed of the monitoring.

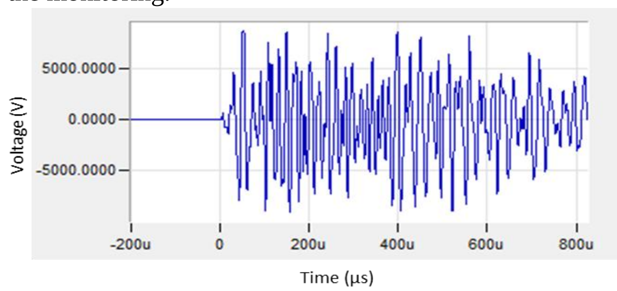

Fig. 6: Event in the middle of the beam to represent tensile mode.

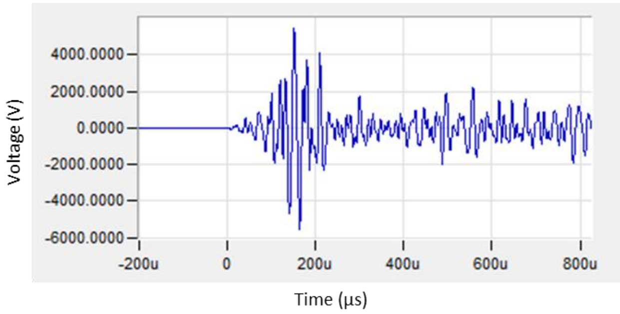

Fig. 7: Event near to support to represent shear mode

IV. CONCLUDING REMARK

This test work describes the application of the AE technique to monitor the concrete beam. Acoustic emission is one of the well-developed nondestructive techniques in monitoring and detecting damage in materials. The ability to detect microcrack at the early phase of damage makes the AE technique interesting. The monitoring and the evaluation of damage in structure by utilizing the AE technique give advantage to assess the level of damage occurred in the structure. The conditions of stability or the risk due to the growth of cracks by means of the counting of hits in order to determine the released energy. Additionally, AE significantly help to determine the stability or instability condition and further forecast the damage in the structure from means of propagation of the cracks.

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AUTHORS PROFILE

Sakhiah Abdul Kudus received her Bachelor and Master degree in Civil Engineering (Structure) from Universiti Sains Malaysia (USM) in September 2011 and May 2014 respectively. In March 2018, she completed her PhD at Kyoto University, Japan with major in Adaptive Structural Engineering area. She has been involved in non-destructive technique (NDT) focusing on Acoustic Emission (AE) since 2010 while completing her final year project at USM. She continues with NDT and structural health monitoring (SHM) research area for her PhD study. Since 1 April 2019, she currently working at Faculty of Civil Engineering, Universiti Teknologi MARA (UiTM), Malaysia as senior lecturer. Her research area covered several topics in field of structural health monitoring, acoustic emission application and analysis, damage assessment, modal analysis, finite element method and high-speed camera.

Adiza Jamadin obtained her Bachelor's degree and Master degree in Civil Engineering (Structure) from Universiti Teknologi Malaysia (UTM) in 2001 and Universiti Teknologi MARA (UiTM) in 2008 respectively. Currently she is working as a Senior Lecturer at Universiti Teknologi MARA (UiTM) since 2009. The research area covered several topics in the field of Structural Health Monitoring (SHM) focusing on experimental, operational modal analysis and finite element method.

Norliyati Mohd Amin obtained her Bachelor's degree and Master of Science in Civil Engineering from Kyushu Universiti Japan and Universiti Teknologi MARA Malaysia in 2007 and 1999 respectively. In 2011, she received her PhD in Structural Engineering from Kyushu University. She has been working with UiTM since January 2001 at the Faculty of Civil Engineering as senior lecturer. She is interested in various kinds of fundamental and applied technologies for civil infrastructures including computational mechanics, Finite Element Method, seismic engineering and structural health monitoring.

Anizahyati Alisibramulisi obtained her bachelor degree and Master in Civil Engineering from Universiti Teknologi Malaysia (UTM). Anizahyati further received her PhD in the field of Structural Engineering from Norwegian University of Science and Technology (NTNU),

Norway. She currently working as a Senior Lecturer at Faculty of Civil Engineering, UiTM. Previously she has worked as Geotechnical Engineer at Jurutera Perunding Zaaba Sdn Bhd and Bridge Engineer at Jurutera Perunding ZAR Sdn Bhd. Her research interest in the areas of structural engineering, through Finite Element Analysis (FEA), process modelling, steel, welded aluminium, timber, concrete and bridge engineering.

Nurul Huda Suliman obtained her PhD from Universiti Teknologi MARA Malaysia in 2019. In 2006, she received a Master's degree in Structural Engineering from Universiti Teknologi MARA Malaysia. Since 2006 onwards she involves in teaching and research and also have published international journal, conference paper and book of chapter. Presently he is a Senior Lecturer at Faculty of Civil Engineering, Universiti Teknologi Mara (UiTM).