

# Reinforced Concrete Beam Monitoring by Utilizing Acoustic Emission Technique

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**Abstract.** This paper presents the capability of Acoustic Emission technique (AE) in the analysis of structural damage condition of a reinforced concrete structure. The objective of the research is to investigate the capability of AE in order to locate and identify the location of the cracks in the reinforced concrete beam which is suspected undergoing the active cracks. The research focus on the classifying the crack whether the crack is active or not. The signal or emission of the each damage is coming directly from the damage region where this emission is produced separately from their own damage region. A parameter-based approach was used to analyses the data acquired by the AE instrumentation. AE activity is evaluated based on the measurement of parameters such as hits, amplitudes and absolute energy. This method of analysis has been shown to be sensitive to the initiation and growth of cracks within both homogeneous and composite materials and structures. In this case, wave propagation velocity was used as a means to evaluate, in more detail, the region indicated by the AE analysis. AEwin software was used to analyses the data collected during the global monitoring. Each defect produced its own emission which can then be evaluated by using AEwin software. Visual observation was done in order to compare the result obtain from the AE system with the result from the visual observation. The results prove that AE technique has a promising technique in the way to detect, locate and monitor the crack at the concrete structure.

**Keywords:** Acoustic emission, cracks location, structural damage

## 1. Introduction

The performance and the stability of this structure will be reduced due to the effect of many factors during the concrete's age. This process usually comes with the development of pores and cracks at the structure [1]. Concrete structures are usually adequately durable for their planned use, but sometimes deteriorate prematurely. So it is important to identify the deterioration early. The deterioration of civil infrastructure worldwide calls for effective methods for damage evaluation and repair. One of them is the Acoustic Emission (AE) monitoring technique. AE is a phenomenon of a transient stress waves resulting from a sudden release of elastic energy, caused by mechanical deformation, initiation and propagation of microcracks, dislocation movement, and at the irreversible change in material [2].

The most important applications of AE to structural reinforced concrete (RC) elements started in the late 1970s, when the original technology developed for metals was modified to suit heterogeneous materials [1,3].

The AE technique is applied to identify defects and damage in RC structures and masonry buildings [4]. This technique permits to estimate the amount of energy released during fracture propagation and to obtain information on the critically of the ongoing process.

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In addition, based on fracture mechanics concepts, a fractal or multistage methodology is proposed to predict the damage evolution and the time to structural collapse. A particular engineering advantage of the AE technique is its efficiency for global monitoring as a large and complex structure can be monitored with a limited number of sensors which this sensor is placed at the specified location of the structure [5]. The AE method promises the safety of the structure and furthermore this technique could reduce the risk control strategies.

The current state of concrete lab structure in the School of Civil Engineering, University Science of Malaysia needs a continuous structural monitoring appraisal. The passive nature of the AE evaluation technique makes it an ideal choice for this purpose.

The objectives of this experiment are to examine the condition of the structural damage using acoustic emission techniques as a non-destructive testing (NDT) technique for reinforced concrete structures, to monitor the cracking and to determine the location of the active cracks which has developed on the structure. The work focuses on the data analysis methods using AEwin software for the detection of active crack within the structure.

## 2. AE Test Methodology

The global monitoring of the deterioration that occurs in concrete lab at the Universiti Sains Malaysia is essential since there are huge cracks located at the structure of the concrete lab. This is important to avoid the building collapse and cause danger to the surrounding people. This test is carried out at the Concrete Laboratory, School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia. The beam is located at the connection between existing building and the new building. The beam located at the additional building of the concrete laboratory that was built in 2005 which is connected to the existing concrete laboratory building. The AE technique has been applied on this beam in order to evaluate the status of the existing cracks.

In AE global monitoring, the totals of 8 R6I sensors were attached to the surface of the beam at the specified location. The location and spacing between the sensors was determined from the attenuation survey. The sensors were placed on longitudinal axis of the beam. The coordination of each sensor at the surface of beam is shown in Figure 1. An essential requirement in mounting a sensor is sufficient acoustic coupling between the sensor face and the structure surface in order to ensure good contact between the two surfaces at microscopic level is achieved.

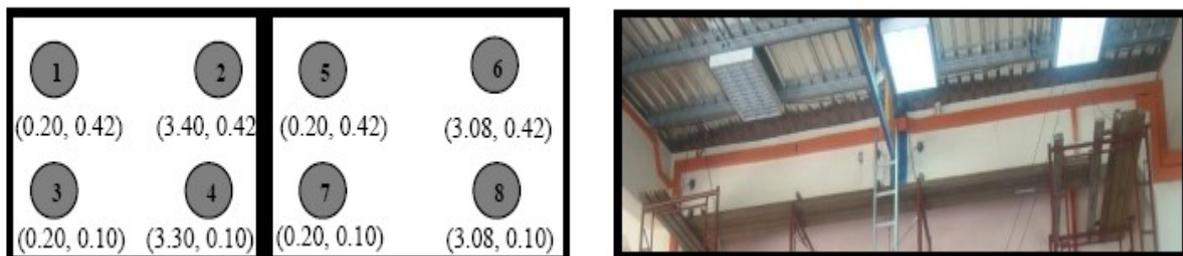


Fig. 1: Coordination of each sensor in X axis and Y axis (unit: meter)

AEwin for micro-SAMOS is the windows based AE acquisition, analysis and replay software program provided with the micro-SAMOS and PCI-8 based systems was used. The AE digital system was used to detect and collect the data during the monitoring. AEwin software allows replaying the data after the monitoring.

### 2.1 Global Monitoring

The structure has been continuously monitored for 2 days, corresponding to 48 hours. Prior to the monitoring, a full AE structural calibration was carried out on the beam by using two sensors. This calibration comprised of the following test by using Hsu-Nielson method [6,7]:

1. Attenuation Survey – Signal attenuation was found to be low (30dB signal loss over 3m) for concrete with pencil break signals readily detected at a distance of 3m from the sensor.

2. Back Ground Noise Check – The environmental noise check established that a comparatively low threshold of 40 dB could be used.
3. Wave Speed Check – The wave speed was calculated as 3455m/s, which was entered into the AE system software to allow accurate location of sources.

### 3. Result and Discussion

The test focuses on the monitoring and classification of the cracks whether the developed cracks on the beam are active or not. It was suspected that the beam undergoing active cracks. From the result of the monitoring, AE method is useful in determine the growth of the micro cracking at the critical area of the structure. A comparison was done between the visual observations of the cracking location and AE source location analysis indicates the area of the cracking, which can be identified by the AE source location technique [8].

From the AE data of the monitoring, there was a pattern of the result obtained. This pattern show there were high numbers of the emission detected when there is the lab work activities carried out and there was only few numbers of emissions being detected by the AE sensor when there is no activities in the lab. The high emission is believed due to the uses of the large machine in the concrete laboratory that produce high noise level and vibration.

#### 3.1 Data Location Display

In this experiment, the typical location display is computed. One of the data location display is a graph of Absolute Energy versus X position. When linear location is being used, the data display is a histogram with the span between the sensors laid out along the X axis. The highest peak shown there have the majority of the emission activity originates. The amount of the energy received by each sensor and the location of the energy released is different from each other. The higher the value of the absolute energy shows that the location need to be give attention due to the highest possibilities of having active cracking activities in that area.

The Figure 2 represents the location of the crack between sensor 3 and 4. From AEWin, the location of the crack located approximately 1.6 meter at the left hand side of the beam, with the value of the absolute energy is  $1.93 \times 10^3$  aJ. While from the visual inspection, the location of the crack is hard to be identified because there are a few cracks which having the same pattern located on the real beam.

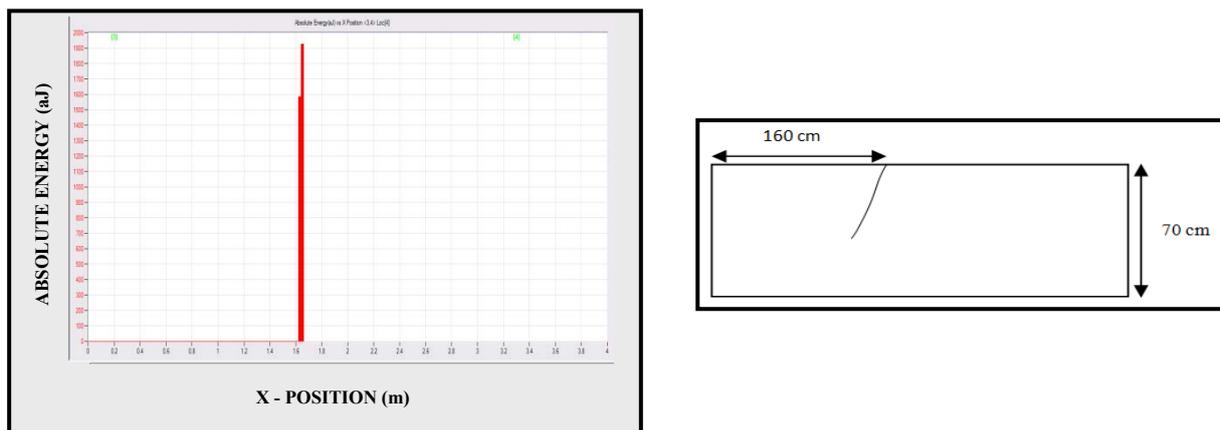


Fig. 2: The location of cracks between Channel 3 and 4

At the location between sensor 1 and 2 in Figure 3, there was a lower number of total absolute energy compare to the absolute energy at sensor 3 and 4. The absolute energy in this region was approximated at  $1.64 \times 10^3$  aJ. The value of the energy from sensor 3 and 4 were higher than value of energy on sensor 1 and 2. This was due to the crack propagating from the compression area to the tension area which was from the top of the beam to the bottom of the beam. Based on AEwin result, the location of the crack is slightly different between sensor 3 and 4, with sensor 1 and 2 due to the setup of the location of the sensor. It was difficult in setting out the sensor in one perfect horizontal line because the location of the beam is high and it hard to make the surface of the beam smooth.

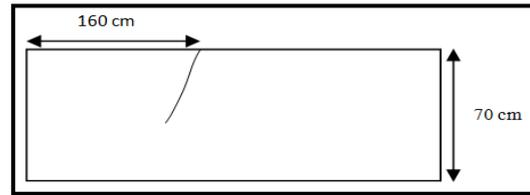
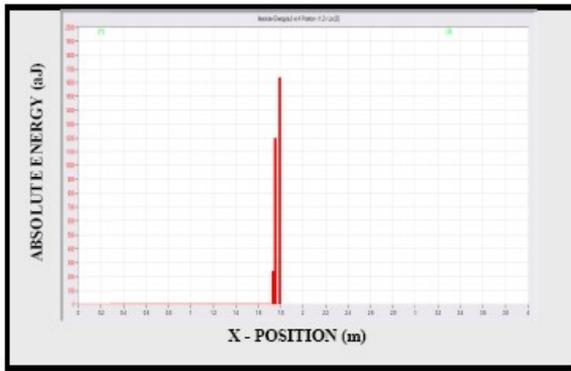


Fig. 3: The location of cracks between Channel 1 and 2

Figure 4 shows the linear location of the crack from the AEwin software and the actual location of the crack on the beam between sensors 7 and 8. Sensor 7 and 8 were located at the bottom of right hand side of the beam. The high value of the cumulative absolute energy located approximately at the 1.5 meter to 1.6 meter. The highest peak in the graph is around  $2.23 \times 10^4$  aJ. This small energy was believed that there was only involved an opening and closing of the same exists cracks. From the visual observation, the massive crack is located approximately 1.6 meter which was at the same location as the result shown in AEwin. The graph in Figure 4 shows that there were several of peaks of absolute energies. This were due to the pattern of the cracks were not in linear directions.

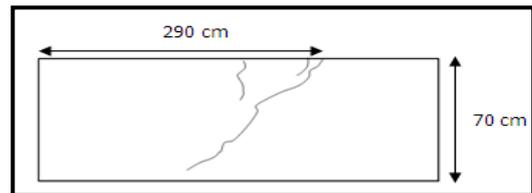
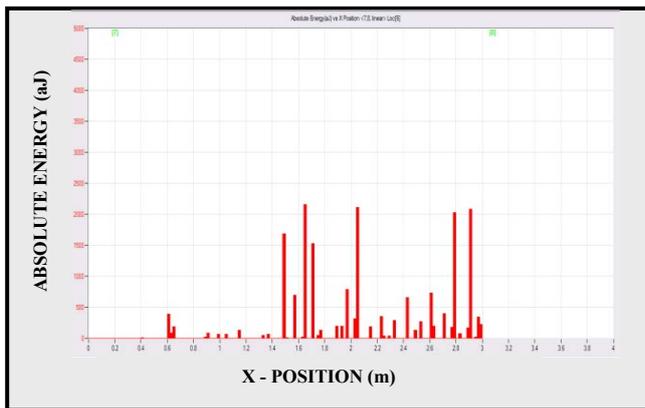


Fig. 4: The location of cracks between Channel 7 and 8

Figure 5 shows the location of the crack between the sensor 5 and 6 on the real beam and the location from the AEwin result. The actual location of the crack on the beam was the same as the crack located between sensor 7 and sensor 8. Based on Figure 5 the higher energy was recorded at  $1.65 \times 10^3$  aJ and the smaller energy value was believed to have occurred due to the opening and closing of the same existing cracks.

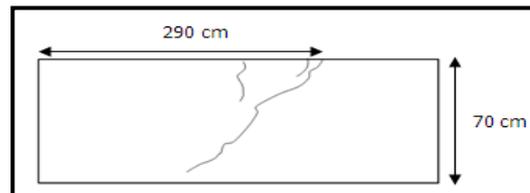
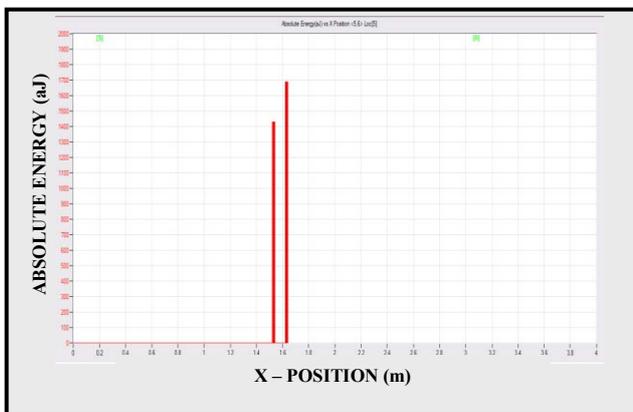


Fig. 5: The location of cracks between Channel 5 and 6

The onset concrete cracking was determined as the absolute energy levels exceed  $1.0 \times 10^6$  attoJoule (aJ) for a single sensor with evidence from the visual observation [7]. But in this analysis, the higher energy recorded does not exceeds  $1.0 \times 10^6$  attoJoule. This means that there is no new crack in this case.

#### **4. Conclusions**

In this test work the stability conditions or the risk due to the spreading of cracks are based on the counting of hits in order to determine the released energy. By monitoring the evaluation of damage by means of the AE technique, it is therefore possible to evaluate the damage level for the structure. AE allow to ascertain stability or instability condition and to forecast the extent of damage in the structure via propagation of the cracks. The results obtained from the monitoring technique seem to indicate that the monitored region has no serious issue with their structural integrity. Continue efforts show that the technique has promising future in becoming an integral part of any structural health monitoring system. Thus, from the absolute energy information it can be concluded that the monitored region had no serious structural damage except for the opening and closing of the existing cracks. The monitoring of building due settlement process give out a very low emission to AE system as compared to monitoring bridge which experienced a dynamic loading from the vehicle.

#### **5. Acknowledgements**

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