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Quantitative Evaluation of the Relationship between Tensile Crack and Shear Movement in Concrete beams

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Abstract. This paper investigates the use of acoustic emission (AE) to identify tensile cracks and shear movements in concrete structures. The analysis of AE signals detected during a concrete beam investigation mainly focused on the relationship between signal parameters namely rise time, amplitude, duration and counts. This method allowed crack classification and shear movements to be identified. A laboratory experiment test was completed on a reinforced concrete beam (150 x 250 x 1900 mm). During testing AE data was captured and analysed post-test. Results from the most severely damaged zone, based on visual inspection, was analysed. The results indicated that tensile cracks developed though out the area of analysis, as confirmed by visual observation and relatively little shear movement occurred as would be expected in a reinforced beam.

Introduction

Recently, concrete structures have been facing a lot of deterioration due to several problems such as, earthquake, fatigue, environmental exposure and increasing age. Consequently, it is necessary to evaluate any damage deterioration to ensure that concrete structures can still with stand their expected service loads. Previous researches proved that the very initial identification of damage at an early help to manage and control the structure safely and economically [1,2]. Therefore, monitoring systems are very important in concrete structure life [3]. Referring to [2], discussed that non-destructive testing (NDT) techniques are needed to identify damage and that acoustic emission (AE) offers a real solution.

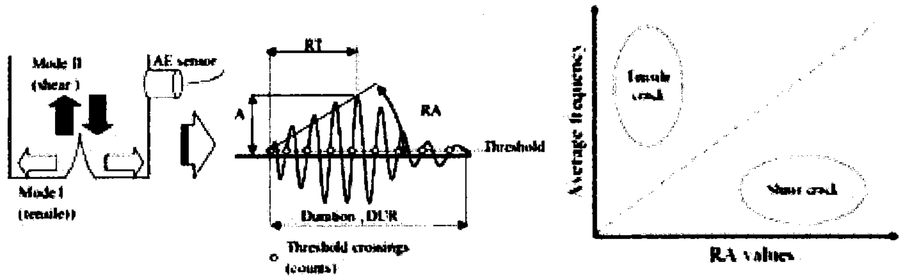
AE has been greatly used in concrete engineering applications since 1970. There are two primary research areas the application of AE to the integrity assessment of concrete structure and exploration of the AE material properties [4]. The AE technique has been used to monitor the fracture process of the structural material and damage behaviour of a material under stress [5-8]. Furthermore, AE measurements have been used to identify and explore the type of cracking in concrete structures [9-14.] and identify corrosion in reinforced concrete structures [15-17].

Even though AE techniques have been extensively used in concrete structures, there has been little research on quantifying the AE data parameters for determining the relationship between tensile cracks and resulting shears movements. Previous researches have investigated crack classifications for tensile and shear cracks using an RA analysis approach [2, 18,] but, the relationship between both types of cracking requires further investigations.

Therefore, this research paper utilised a concrete beam specimen to evaluate and investigate the relationship between tensile cracks and shear movements at the support area by utilising the RA value analysis approach.

RA Value Analysis

In general, the RA analysis approach is one of the simplest AE analysis techniques to classify the type of cracking mode present in concrete. The method allows tensile crack (Mode Type I) and shear crack (Mode Type II) to be characterised. This method involves examining the amplitude, rise time and average frequency of detected AE signals. The relationship between these parameters is shown Fig 1 (where mode II represents a shear movement) and Equations 1 and 2:



(a) (b)

Fig 1 (a) Cracking mode in AE signal [2] and (b) crack classification [19]

$$\mathrm{RA} = {}^{\text{Rise time}}/_{\text{Amplitude}} \tag{1}$$

$$\text{Ave. Frequency} = {}^{\text{Counts}}/_{\text{Duration}} \tag{2}$$

In this method, crack Mode Type I (tensile) are nucleated in the initial stages of the fracture process and subsequently a sliding movement will occur and generate crack Mode Type II (Shear)[19]. In general when the RA value of a signal is small and the average frequency is high signals are from tensile events. However when this is reversed signals are said to be for shear cracks as seen in Fig 1.

Experimental work

Concrete beam specimens were manufactured based on the BS8110 with cross section 150mm X 250mm X 1900mm and tested in four point bending. The specimens were reinforced with high tensile strength seen in Fig 2. The specimens were tested in four points bending with an applied load speed of 0.5mm/min using a hydraulic jack (Fig. 2). A cyclic load (CLT) was applied with the starting value 0.5kN. The first loading cycle was increased up to 20% of calculated ultimate load and held for 3 minutes then released to 10% of the calculated ultimate load and held for a further 3 minutes before the next cycle was applied. This loading and hold procedure was continued with increasing load until ultimate failure.

Throughout the testing, the specimens were monitored by AE sensor R6I (40 –100 kHz) as seen in Fig 2. The mounted sensitivity of the AE system sensitivity was assessed prior to start the loading [20].

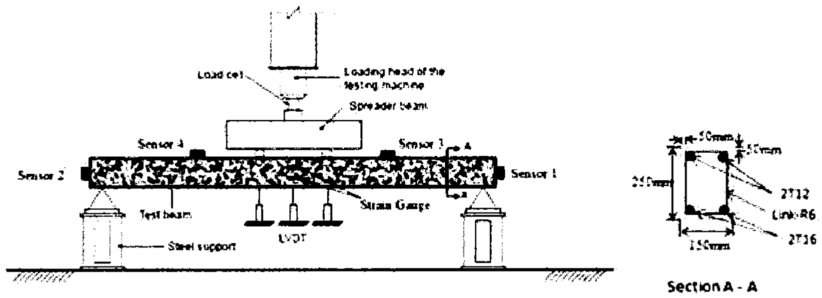


Fig 2 Specimen setup and dimensions

Result and Discussion

For this investigation a partial analysis is reported. An area under one loading point was selected to analyse the collected signals in terms of RA and AF. Fig **3** shows the location of signals along the length of the beam. Each point on the plot represents a located AE signal, whilst the green boxes indicate sensor positions. The area for analysis performed is shown by a black box and represents an area where large amounts of tensile cracking occurred as confirmed by visual inspection as seen in Fig **3**. The corresponding visual observation is shown in Fig **4**.

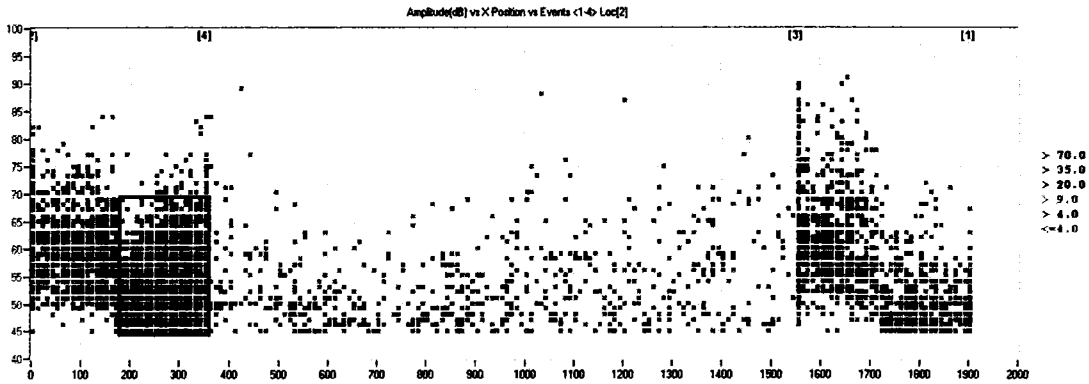


Fig 3 Event location based on amplitude

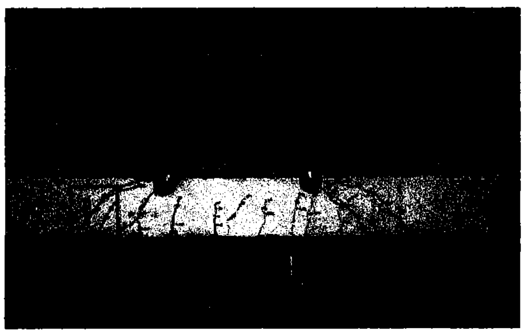


Fig 4 Visual Observations

When comparing Fig 3 and Fig 4 it can be seen that the majority of cracking occurred between sensors 2 and 4 and hence the greatest amount of AE activity is located in this area. Fig 5 shows the traditional graph RA versus AF plots was described in Fig 1.

The graph pattern shows that initially the detected signals were predominantly tensile in nature however as the specimen damage increases shear movement can occur. However as there is a large amount of reinforcement in the beam the shear movement is restricted and hence more tensile cracking occurs. This is clearly evidenced in Fig 5 where the majority of located signals throughout the test are tensile with some shear movements as damage increases.

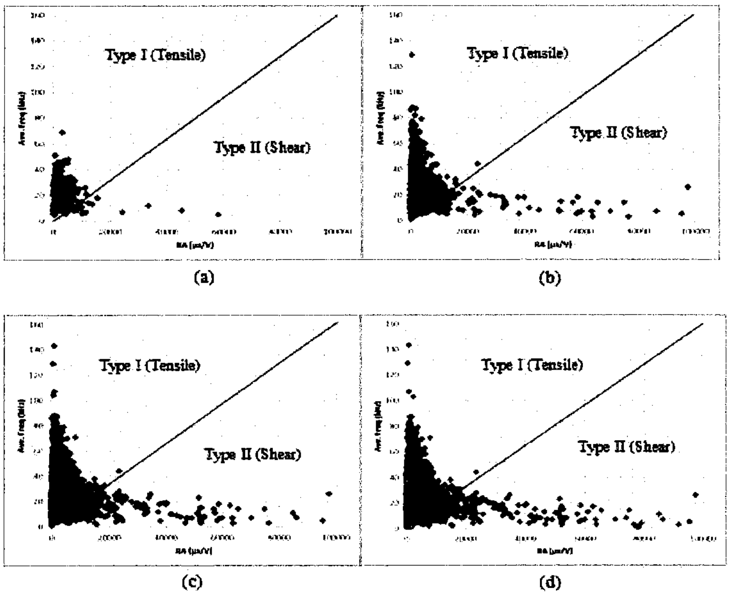
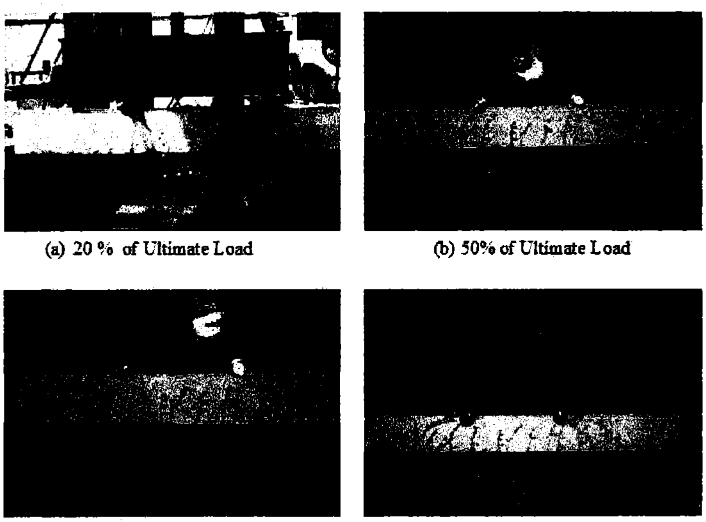


Fig 5 Beams conditions by percentage of loading

Fig 6 shows photographs of the beam during loading showing tensile cracks and possible shear movements. From these observations, the results of the AE analysis can be validated. The plots show large amounts of tensile cracks and further visual observation noted little shear movement due to the steel reinforcement. Further research needs to be completed that can quantify shear movements and applications to real structures require investigating. If successful this approach offers real opportunity for asset management and furthermore will provide bridge engineers with important information for assessing remaining life.



(a) 20 % of Ultimate Load (b) 50% of Ultimate Load

(c) 80% of Ultimate Load (d) Failure

Fig 6 Result in real observation

Conclusion

In this paper a study was performed that examined the relationship between tensile cracks and shear movements in a concrete reinforced beam. It was found that the majority of signals detected were tensile in nature and only limited shear movement occurred. This is keeping with the steel reinforced beam. The approach presented offers real potential for asset management and safety inspections

References:

[1] Benavent, A., E. Castro and A. Gallego (2010). "Evaluation of low-cycle fatigue damage in RC exterior beam-column subassemblages by acoustic emission." Construction and Building Materials 24(10): 1830-1842.

[2] Aggelis, D. G. (2011). "Classification of cracking mode in concrete by acoustic emission parameters." Mechanics Research Communications 38(3): 153-157.

[3] Ohtsu, M. (1996). The history and development of acoustic emission in concrete engineering. Magazine of Concrete Research,. 48.

[4] Beck P., Bradshaw T. P., Lark R. J. and H. K. M. (2003). "A Quantitative study of the realationship between concrete crack parameters and acoustic emission energy released during failure " Engineering Materials 245-246: pp 461-466.

[5] Ohtsu, M. and K. Ono (1988). "AE source location and orientation determination of tensile cracks from surface observation." NDT International 21(3): 143-150.

[6] Kawasaki, Y., Y. Tomoda and M. Ohtsu (2010). "AE monitoring of corrosion process in cyclic wet-dry test." Construction and Building Materials

[7] Aggelis, D. G., D. V. Soulioti, N. Sapouridis, N. M. Barkoula, A. S. Paipetis and T. E. Matikas (2011). "Acoustic emission characterization of the fracture process in fibre reinforced concrete." Construction and Building Materials 25(11): 4126-4131.

[8] Shahidan, S., N. M. Bunnori, N. M. Nor and S. R. Basri (2012). "Health Index Evaluation on Acoustic emission Signal for concrete Structure by Intensity Analysis Method." Advanced Materials Research 403-408: 3729-3733

[9] Grosse, C., H. Reinhardt and T. Dahm (1997). "Localization and classification of fracture types in concrete with quantitative acoustic emission measurement techniques." NDT & E International 30(4): 223-230

[10] Ohtsu, M., T. Okamoto and S. Yuyama (1998). "Moment Tensor Analysis of Acoustic Emission for Cracking Mechanisms in Concrete." ACI Structural Journal 95(2): 87-93.

[11] Kapphahn, G. and V. Slowik (2008). Acoustic Emission Analysis during Test Loading of Existing Structures. Acoustic Emission and Critical Phenomena, Taylor & Francis: 155-165

[12] Carpinteri, A., G. Lacidogna and S. Puzzi (2009). "From criticality to final collapse: Evolution of the "b-value" from 1.5 to 1.0." Chaos, Solitons & Fractals 41(2): 843-853.

[13] Ohno, K. and M. Ohtsu (2010). "Crack classification in concrete based on acoustic emission." Construction and Building Materials 24(12): 2339-2346

[14] Van Tittelboom, K., N. De Belie, F. Lehmann and C. U. Grosse (2012). "Acoustic emission analysis for the quantification of autonomous crack healing in concrete." Construction and Building Materials 28(1): 333-341.

[15] Farid Uddin, A. K. M., K. Numata, J. Shimasaki, M. Shigeishi and M. Ohtsu (2004). "Mechanisms of crack propagation due to corrosion of reinforcement in concrete by AE-SiGMA and BEM." Construction and Building Materials 18(3): 181-188.

[16] Ramadan, S., L. Gaillet, C. Tessier and H. Idrissi (2008). "Detection of stress corrosion cracking of high-strength steel used in prestressed concrete structures by acoustic emission technique." Applied Surface Science 254(8): 2255-2261.

[17] Muhamad Bunnori, N., K. M. Holford and R. J. Lark (2011). "The use of acoustic emission for the early detection of cracking in concrete structures." Magazine of Concrete Research 63(1): 1-6.

[18] Ohno, K. and M. Ohtsu (2010). "Crack classification in concrete based on acoustic emission." Construction and Building Materials 24(12): 2339-2346.

[19] Grosse, C., M. Ohtsu and T. Shiotani (2008). Parameter Analysis. Acoustic Emission Testing, Springer Berlin Heidelberg: 41-51

[20] ASTM-E976 (2011). E976 -11. Standard Guide for Determining the Reproducibility of Acoustic Emission Sensor Response. United State, American Society of Testing Material.

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