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APPLICATION OF ACOUSTIC EMISSION TESTING IN ORDER TO UNDERSTAND MODE I FRACTURE PROCESS IN STEEL FIBRE REINFORCED CONCRETE

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Abstract

This article presents characteristics of acosutic emissions (AE) generated during mode I fracture process in steel fibre reinforced concrete (SFRC). Three point bend SFRC specimens were tested in the laboratory by following EN-14651-2005 guidelines. A 2D planar location was adopted to mount the four 57 kHz resonant type AE sesnors on the test specimen to record the generated AE. The number of AE events reduced with the increase in the steel fiber content under the same experimental conditions. The fracture process zone (FPZ) was divided into major damage zone comprised of AE events with (i) high peak amplitude, (ii) low information entropy (iii) longer AE waveform duration. The major damage zone was located ahead of the notch tip very closely. AE testing is a useful testing method to study the fracture process in SFRC.

1. Introduction

The fracture properties of a brittle cementitious matrix can be enhanced by incorporating short-fiber reinforcements. The steel fibers are an effective means for dissipating energy. The FPZ ahead of the crack tip, induces nonlinearity in the stress-strain behavior of quasi-brittle materials. A phenomenon in which sound is generated by the energy released during the fracture process in a solid is referred to as AE (or stress wave emiassion). Analysis of these generated stress waves can provide information regarding the fracture process in a solid. Due to the capability of AE testing to detect microcracking in the material, it has been used to study fracture process in materials [1]. Most of the studies related to FPZ in SFRC under mode I fracture and AE testing have been limited to using conventional AE waveform parameters such as (i) AE Energy and (ii) AE peak amplitude [2]. However, in this study, an attempt has been made to segregate the AE events into three different damage zones utilizing two new AE parameters (i) AE information entropy and (ii) Gutenberg-Richter exponent values. The area of the damage zones was also computed using AutoCAD. In the current study, an attempt has been made to employ AE waveform parameters to characterize the FPZ in SFRC and locate the different-damage zones in SFRC under Mode I fracture. Damage is typically defined as the material deterioration that takes place before failure as a result of the accumulation of microcracks. Moreover, a region where an accumulation of microcracks exists close to the crack tip, which constitutes the FPZ, can be identified as a zone of damage. The present study adopts methodologies including, (i) AE Information entropy (ii) Gutenberg-Richter exponent (iii) AE duration (iv) AE peak amplitude (v) AE peak frequency to analyse the AE waveform and parametric data and understand the FPZ in SFRC test specimens. In the present study three point bend beam speicmens (500 mm X 150 mm X 150 mm) were tested in the laboratory and simultaneously the generated AE was recorded. The notch depth was 25 mm. In **Table 1** the cementitious mixture proportions, steel fiber volume fraction (V_f), and the loading rate are given. Double hooked-ended steel fibre was used in the SFRC mixture. The length of each steel fibre is 30 mm and the diameter is 0.5 mm. The aspect ratio is 60.

Table 1. Material properties

Specimen	V_f (%)	Cementitious Mixture	Hits	Counts	Energy (V-s)	Loading Rate (CMOD Controlled) (mm/s)
PCC-1	0	Cement: CA: FA = 1:1.77:2 w/c = 0.45 by weight	476062	13947956	17181133	0.0008
PCC-2			248373	21751173	24798149	
B1-4	0.8	Cement: CA: FA = 1:1.75:2 w/c = 0.45 by weight	172589	29090299	20830866	(i) 0.0008 mm/s till CMOD = 0.1 mm (ii) 0.0033 mm/s till CMOD = 4 mm
B1-5			424802	12646202	10326927	
B1-6			355468	13029807	9819218	
B2-4	1.6	Cement: CA: FA = 1:1.73:1.94 w/c = 0.45 by weight	18176	135412	404014	(i) 0.0008 mm/s till CMOD = 0.1 mm (ii) 0.0033 mm/s till CMOD = 4 mm
B2-5			28812	216097	503616	
B2-6			17272	114918	274490	

2. Results

High peak amplitude events (90 dB – 100 dB) were observed in the major damage zone of the FPZ and close to the notch of the TPB specimen. The classification of damage zones based on AE parameters and Gutenberg-Richter (G-R) exponent (ε) was given in **Table 2.**

Table 2. Classification of damage zones based on AE parameters and Gutenberg-Richter (G-R) exponent (ε).

Sl. No.	Zone	AE waveform				CMOD (mm)	G-R exponent (ε)	
		Peak Amplitude (dB)	Information Entropy (bit)	Peak Frequency (kHz)	Duration (μs)		V_f=0.8%	V_f=1.6%
1	Major Damage	91 - 100	0.80 - 0.98	250 – 101	1500 – 2500	2.45-4.00	1.105	1.160
2	Moderate Damage	71 - 90	0.99 - 1.00	81 – 100	501 – 800	0.45-2.44	1.140	1.190
3	Low Damage	45 - 70	>1.00	24 – 80	80 – 500	0.1-0.44	1.195	1.232

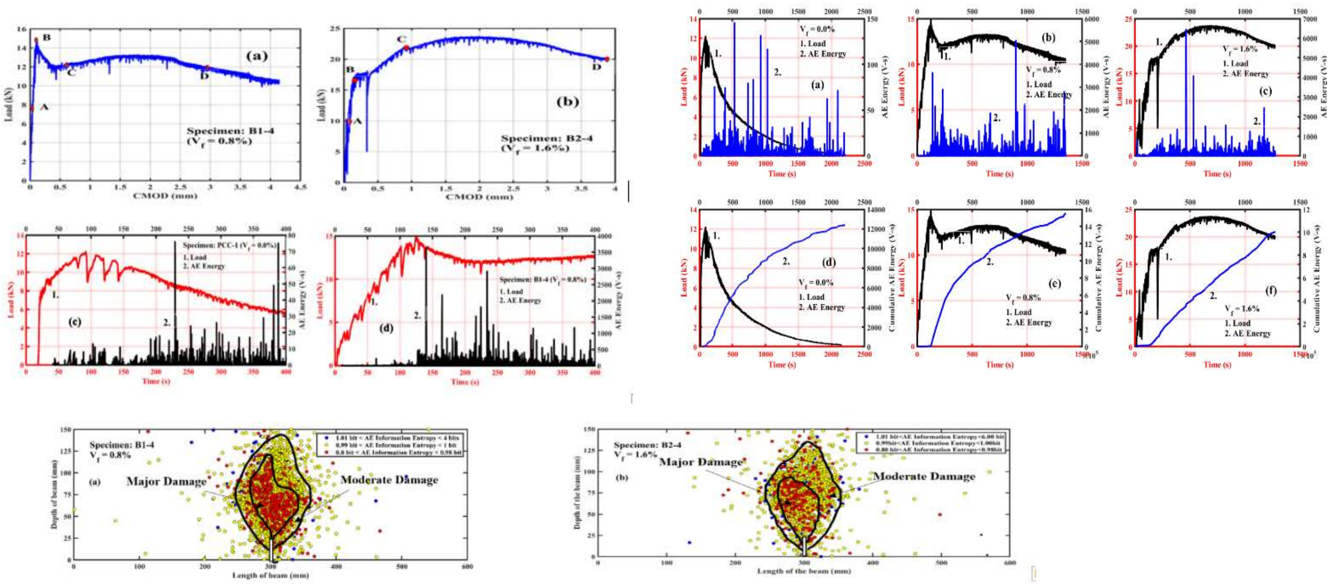

Fig.1. *Load-CMOD response of SFRC specimens with (a)V_f = 0.8% (b) V_f = 1.6%; AE characteristics of the steel fiber reinforced TPB specimens from start to 400s for specimens having (c) V_f = 0.0% (d) V_f = 0.8%. Distribution AE information entropy for specimens with (a) V_f = 0.8% ; (b) Vf = 1.6% in the FPZ.*

Variation of the AE peak amplitude distribution away from the notch showed an increase in low peak amplitude AE events and the number of high amplitude events almost constant. The distribution of the AE events based on the AE information entropy values showed a concentration of low entropy AE events in the major damage zone of the FPZ. Distribution of the AE events based on the AE duration showed a concentration of high duration AE events in the major damage zone of the FPZ which corresponds to steel fiber pullout events. The AE duration in this zone as shown in **Fig. 1** varied from 1500 μs to 2000 μs. The distribution of AE waveform duration changed significantly for lower duration events away from the notch.

3. Conclusions

The number of high-duration AE events remained the same after a certain distance from the notch. Distribution of the AE events based on the G-R exponent values showed a concentration of low G-R exponent values in the major damage zone which was located close to the notch. This indicated that a decrease in the G-R exponent value is related to the damage to the material. The area of major damage decreases as the volume fraction of steel fibers in the SFRC specimen increases. It is also observed that the area of the major damage zone is directly impacted by the reduction in AE events with rising steel fiber volume percentage.

4. References

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