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An experimental study on loading rate effect on acoustic emission based *b*-values related to reinforced concrete fracture

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HIGHLIGHTS

- *b*-Values analysis was performed to study fracture process in reinforced concrete T-beams.
- AE based *b*-values are compared with strain in steel reinforcement in T-beams.
- Concrete relatively more brittle at higher loading rates.
- *b*-Values are lower in average as a few and strong cracking AE events occured at higher loading rates.

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ABSTRACT

This article reports on analysis of fracture processes in reinforced concrete (RC) beams with acoustic emission (AE) technique. An emphasis was given to study the effect of loading rate on variation in AE based *b*-values with the development of cracks in RC structures. RC beams of length 3.2 m were tested under load control at a rate of 4 kN/s, 5 kN/s and 6 kN/s and the *b*-value analysis available in seismology was used to study the fracture process in RC structures. Moreover, the *b*-value is related to the strain in steel to assess the damage state. It is observed that when the loading rate is higher, quick cracking development lead to rapid fluctuations and drops in the *b*-values. Also it is observed that concrete behaves relatively more brittle at higher loading rates (or at higher strain rates). The average *b*-values are lower as a few but larger amplitudes of AE events occur in contrast to more number of low amplitude AE events occur at low loading rates (or at low strain rates).

1. Introduction

The issue of monitoring fracture process in concrete structures is always open, since many points need clarification. The fracture characteristics of RC structural members are affected by loading rates [1]. AE released during fracture process in real scale components still needs refinement. It is known that both concrete and steel are loading rate dependent materials. Strength, stiffness, brittleness, ductility of concrete and steel are affected by loading rates. A survey on response of RC structures subjected to different loading rate has been presented [2]. The physical mechanism involved in the behavior of concrete in tension at different loading rates was summarized and the study concluded that at smaller strain rates the physical mechanism is a viscous mechanism known as Stefan effect which counter both microcracking and macrocrack propagation. At high strain rates the forces of inertia counter the microcracking localization and propagation. The viscous effects, together with the forces of inertia results in increasing the Young's modulus and tensile strength of the concrete [3].

Zhang et al. studied fracture behavior of high-strength concrete at various loading rates. The fracture energy and the peak load were measured. The study concluded that the fracture energy and the peak load increase as the loading rate increases. Under high loading rates the increase in the fracture energy and peak load are influenced due to the effect of inertia [4]. The strength and the elastic modulus of concrete increased with the increasing loading rate. Also the yield strength and the corresponding strain of steel increased with the increasing loading rate. Muller reviewed the experimental data available on fracture properties of high strength concrete subjected different loading rates [5]. Su et al. studied the loading rate effect on mechanical properties of concrete used for hydraulic structures using AE technique and concluded that as the strain rate increases, the cumulative AE events, hits, hit rate around peak stress decrease correspondingly for the same size of specimens [6].

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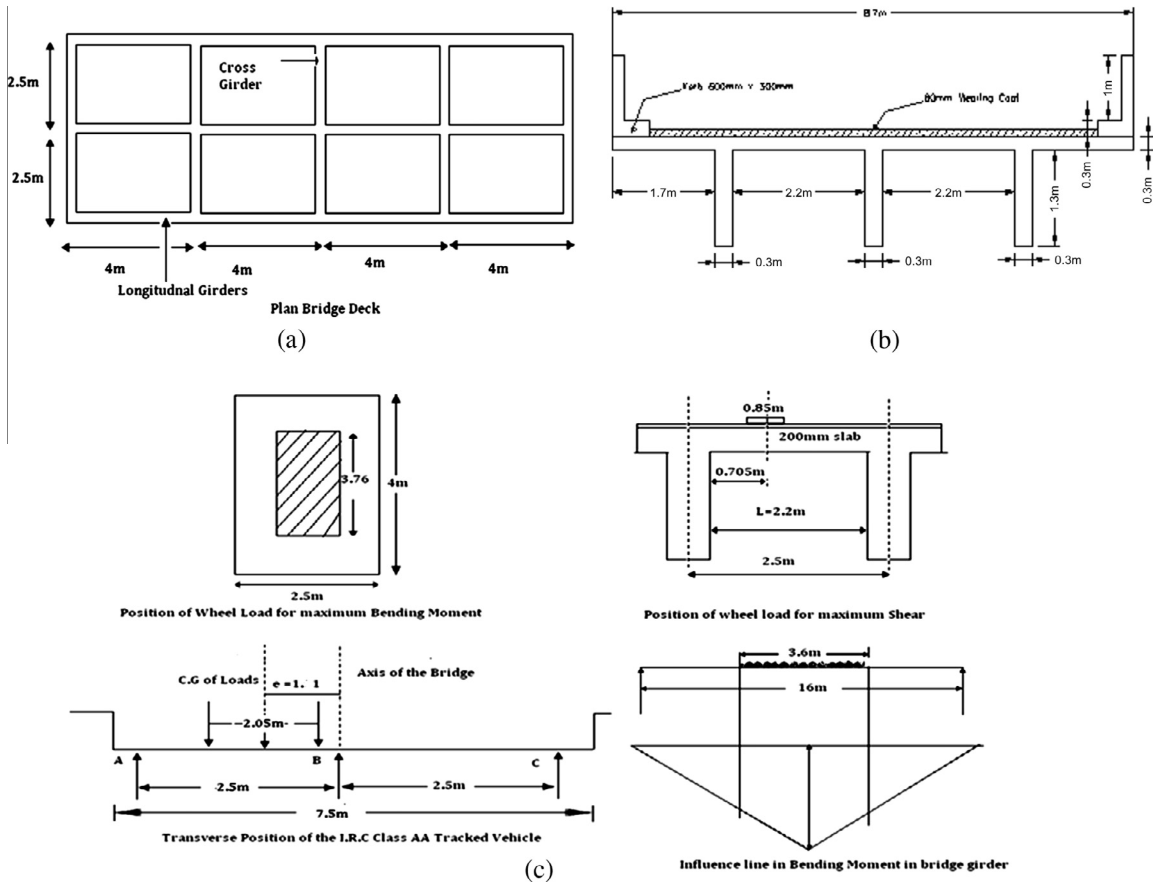

Fig. 1. (a) Bridge deck plan (b) cross section of the bridge deck, [kerb 600 mm × 300 mm, deckslab thickness 0.2 m, breadth of cross girder is 0.3 m, wearing coat is 0.08 m, carriage ways is 7.5 m] (c) application of load on bridge.

Table 1
Design moments and shear forces.

	Bending moment (kN-m)			Shear force (kN)		
	Dead load	Live load	Total	Dead load	Live load	Total
Outer girders	1218	1513	2731	292	280.1	572.1
Inner girder	1218	912	2130	292	402.6	694.6

Table 2
Geometric details of the RC test beams (*X* and *Y* are the sensor location/coordinates in *XY*-plane; The name LC2M37 stands L for large specimen, c for concrete, 2 for second specimen, M37 stands for concrete mix having 28th day strength of 37 MPa).

Specimen	∅ (mm)	n	A_s (mm^2)	S (mm)	L (mm)	Total depth D (mm)	T-beam Flange		T-beam Web(rib)		Rate of loading (kN/s)	Sensor location (mm)											
							Depth (mm)	Width W_f (mm)	Depth (mm)	Width W_{rib} (mm)		1		2		3		5		6		8	
												X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
LC2M37	20	4	1256	2600	3210	560	180	500	380	180	4	460	300	900	240	1600	175	2000	160	2400	210	2800	190
LLR3	20	4	1256	2600	3210	560	180	500	380	180	5	460	300	900	240	1600	200	2000	160	2420	230	2800	200
LLR1	20	4	1256	2600	3210	560	180	500	380	180	6	460	300	900	240	1600	200	2000	160	2400	230	2800	200

∅ is the diameter of reinforcing bar; n is number of main reinforcing bars; S is span of the test beam; L is the total length of the test beam.

The issues such as monitoring fracture process in concrete structures using AE technique concern mainly the interpretation of AE parameters which in many cases is subject to assumptions that although reasonable they are still assumptions. Loading rate effect on AE based *b*-values related to fracture process in RC structures may help to clear the trends and useful in order to build the experience of the AE and concrete community working in structural health monitoring research area.

Only few design codes take into account the effect of loading rates on the RC structures. There is a need to do structural health monitoring tests and confirm old RC structures performance and safety. Because in India there are many RC structures constructed