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Acoustic emission monitoring of damage progression in CFRP retrofitted RC beams

Archana Nair[a], C.S. Cai*, Fang Pan[b] and Xuan Kong[c]

Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA, 70803, USA

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Abstract. The increased use of carbon fiber reinforced polymer (CFRP) in retrofitting reinforced concrete (RC) members has led to the need to develop non-destructive techniques that can monitor and characterize the unique damage mechanisms exhibited by such structural systems. This paper presented the damage characterization results of six CFRP retrofitted RC beam specimens tested in the laboratory and monitored using acoustic emission (AE). The focus of this study was to continuously monitor the change in AE parameters and analyze them both qualitatively and quantitatively, when brittle failure modes such as debonding occur in these beams. Although deterioration of structural integrity was traceable and can be quantified by monitoring the AE data, individual failure mode characteristics could not be identified due to the complexity of the system failure modes. In all, AE was an effective non-destructive monitoring tool that can trace the failure progression in RC beams retrofitted with CFRP. It would be advantageous to isolate signals originating from the CFRP and concrete, leading to a more clear understanding of the progression of the brittle damage mechanism involved in such a structural system. For practical applications, future studies should focus on spectral analysis of AE data from broadband sensors and automated pattern recognition tools to classify and better correlate AE parameters to failure modes observed.

Keywords: acoustic emission; reinforced concrete; CFRP; intensity analysis

1. Introduction

Retrofitting reinforced concrete (RC) structures using materials such as fiber reinforced polymers (FRP) has gained popularity in the past decades. This has been mainly due to the maintenance and repair requirements of existing civil infrastructure and the versatile features of FRP composites, such as light weight, ease in onsite application, good corrosion resistance, etc. However, for RC beams externally retrofitted with FRP the debonding failure mechanism has been deemed the most critical failure mode (Teng *et al*. 2001). There have been numerous efforts to counter this form of failures, yet the complex nature of this failure mechanism has not led to convincing mitigation solutions. Thus, there is a genuine need for a real time non-destructive

*Corresponding author, Edwin B. and Norma S. McNeil Distinguished Professor, E-mail: cscai@lsu.edu
[a] Research Assistant
[b] Research Assistant
[c] Research Assistant

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deterioration, Master's thesis, University of Texas, Austin, Tx.

Committee on Acoustic Emission from Reinforced Plastics (CARP) (1987), *Recommended practice for acoustic emission of fiberglass reinforced plastic resin (RP) tanks/vessels*, Composites Institute, Society of the Plastics Industry, New York.

Degala, S., Rizzo, P., Ramanathan, K. and Harries, K.A. (2008), "Acoustic emission monitoring of CFRP reinforced concrete slabs", *Constr. Build. Mater.*, **23**(5), 2016-2026.

Fowler, T.J., Blessing, J.A. and Conlisk, P.J. (1989), "New directions in testing", *Proceedings of the 3rd International Symposium on Acoustic Emission from Composite Materials*, Paris, France, July.

Fowler, T.J., Blessing, J.A. and Strauser, F.E. (1992), "Intensity analysis", *Proceedings of the 4th International Symposium on Acoustic Emission from Composite Materials*, American Society for Nondestructive testing, Columbus Ohio.

Ghorbanpoor, A. and Rentmeester, A.T. (1993), "NDE of steel bridges by Acoustic emission", *Proceedings of the Structural Engineering in Natural Hazards Mitigation*, ASCE, Irvine, California, April.

Golaski, L., Gebski, P. and Ono, K. (2002), "Diagnostics of reinforced concrete bridges by acoustic emission", *JAE*, **20**, 83-98.

Gostautas, R.S., Ramirez, G., Peterman, R.J. and Meggers, D. (2005), "Acoustic emission monitoring and analysis of Glass Fiber-reinforced composites bridge decks", *J. Bridge Eng.- ASCE*, **10**(6), 713-721.

Henkel, D.P. and Wood, J.D. (1991), "Monitoring concrete reinforced with bonded surface plates by the acoustic emission method", *NDT & E Int.*, **24**(5), 139-147.

Johnson, D.E., Shen, H.W. and Finlayson, R.D. (2001), "Acoustic emission evaluation of reinforced concrete bridge beam with graphite composite laminate", *Smart Struct. Mater.*, **4330**, 498-504.

Lau, K.T., Yuan, L.B., Zhou, L.M, Wu, J.S. and Woo, C.H. (2001), "Strain Monitoring in FRP Laminates and Concrete Beams Using FBG Sensors", *Compos. Struct.*, **51**, 9-20.

Levar, J. and Hamilton, H. (2003), "Nondestructive evaluation of carbon fiber-reinforced polymer-concrete bond using infrared thermography", *ACI Mater. J.*, **100**(1), 63-72.

Mirmiran, A, Shahawy, M, and El Echary, H. (1999), "Acoustic emission monitoring of hybrid FRP–concrete columns", *J. Eng. Mech. - ASCE*, **125**(8), 899-905.

Mirmiran, A. and Wei, Y. (2001), "Damage assessment of FRP-encased concrete using ultrasonic pulse velocity", *J. Eng. Mech. -ASCE.*, **127**(2), 126-135.

Mirmiran, A. and Philip, S. (2000), "Comparison of acoustic emission activity in steel-reinforced and FRP-reinforced concrete beams", *Constr. Build Mater*., **14**(6), 299-310.

Ohtsu, M., Uchida, M., Okamoto, T. and Yuyama, S. (2002), "Damage Assessment of reinforced concrete beams qualified by Acoustic emission", *ACI Struct. J.*, **99**(4), 411-417.

Park, J.Y., Cho, H.D., Han, H.S. and Choi, M.Y. (2004), "Detection of crack source location on RC structures strengthened with CFRP plate for health monitoring system", *Key Eng. Mat.*, **270-273**, 1971-1976.

Ridge, A.R. and Ziehl, P.H. (2006), "Evaluation of strengthened reinforced concrete beams: cyclic load test and acoustic emission methods", *ACI Struct. J.*, **103**(6), 832-841.

Teng, J.G., Chen J.F., Smith, S.T. and Lam, L. (2001), *FRP-strengthened RC Structures*, John Wiley & Sons, U.K.

Whitten, L.S., Joel P., Conte and Eric, U. (1999), "Long gage fiber fragg grating sensors to monitor civil structures", *SPIE*, **4330**, 56-65.

Yuyama, S., Okamoto, T., Shigeishi, M., Ohsu, M. and Kishi, T. (1999), "A proposed standard for evaluating structural integrity of Reinforced Concrete Beams by Acoustic emission", Acoustic emission: Standards and Technology update, ASTM STP 1353, (Ed. S.J. Vahaviolos), American Society for testing and materials, West Conshohocken, PA.