FINAL REPORT

Steel Girder Supporting Bridges: An Experimental Study and Theoretical Analysis to Evaluate Structural Integrity of Steel Girders

Principal Investigator
Vitaly Khaykin

Department of Engineering
Hampton University
Hampton, VA 23668

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DISCLAIMER

ABSTRACT

Safety and integrity of the national transportation infrastructure are of paramount importance and highway bridges are critical components of the highway system network. This network provides an immense contribution to the industry productivity and economic competitiveness. The infrastructure maintenance efforts must ensure a safe, timely, and reliable means of determining possible structural failures without undue disruptions to the traffic flow. As part of the National Center for Intermodal Transportation and Economic Competitiveness, with the assistance of the Virginia Department of Transportation, the application of the acoustic emission non-destructive testing methods is investigated for detecting and assessing structural conditions of the steel girder highway bridges. Acoustic emission can be used to identify suspected areas of the structure and helps to evaluate whether any further testing and analysis is warranted. A follow up acoustic emission data research was conducted at the interstate I-664 bridge crossing in Newport News, VA.

ACKNOWLEDGMENTS

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INTRODUCTION

The theme of the National Center for Intermodal Transportation and Economic Competitiveness (NCITEC) project is to promote the development of an integrated, economically competitive, efficient, safe, secure, and sustainable national intermodal transportation network by integrating all transportation modes for both freight and passenger mobility. Safety is a critical component in the development, implementation, operation and maintenance of the transportation system, and therefore it is imperative to conduct research on utilization of technologies that will allow enhancement of the highway structures safety by monitoring and predicting failures.

Highway bridges are a vital part of transportation infrastructure and there is need for reliable non-destructive methods to monitor their structural condition to ensure safety and efficiency. Many factors lead to the deterioration of highway bridges, including aging, extreme events such as natural disasters, other hazards including negligence, improper maintenance, and collisions, and, most importantly, operational loads from the increased freight transportation truck weights. Bridge structures, being vital for safety and economics, need the best protection, and the evaluation of their integrity becomes paramount. The ability to obtain necessary information regarding the bridge technical condition is often expensive and time consuming; furthermore, the inspection methods and techniques used need to be non-destructive, devoid of introducing any new damage during the monitoring process. With these goals in mind, this research addresses the application of the acoustic emission (AE) non-destructive testing (NDT) technology to evaluate and monitor the highway bridge integrity.

In this brief extension project, a follow-up investigation was conducted at the I-664 Newport News bridge site to determine any changes to the AE activity levels that could have resulted from the existing defect of the steel girder or from any new flaws that could have formed in the bridge structure. This extension project is a continuation of the previous effort by the Hampton University (HU) researchers in the area of acoustic emission monitoring and analysis of the interstate I-664 bridge crossing over Terminal Ave. in Newport News, VA (southbound lanes). This bridge forms part of the Hampton Roads Beltway in the vicinity of the Monitor-Merrimac Memorial Bridge-Tunnel crossing, handles significant heavy truck traffic, and is located in the immediate proximity to the railroad serving the CSX Railroad Coal Loading Dock in Newport News, VA.

OBJECTIVE

The overarching goal of this work is to advance the state of art in the steel girder bridge structural monitoring via the use of AE technology to reduce the conventional time and effort required to inspect such bridges for their integrity and safety. The impact will include the advancement of the NDT technology application expertise by utilizing the AE technology for data acquisition and real-time analysis for prediction of factors that lead to deterioration and wear in the highway structural components under the stresses of traffic environment. The objective is to determine methodology to identify defects within the bridge structure utilizing their AE footprint.

This project's goal is twofold. Firstly, it addresses the problems of evaluation of highway bridges and structures within the intermodal environment by using the AE technology to conduct assessment of their condition to assure that they are in the "state of good repair" and provide early indications of structures with deficiencies. Secondly, this work enhances HU capabilities and minority students' participation in the transportation-related projects by actively engaging them in the research, thus forming the next generation of transportation workforce. This research directly affects the *Safety* and the *State of Good Repair* strategic goals of the U.S. DOT, therefore also impacting the *Economic Competitiveness* goal.

SCOPE

The scope of the current follow-up work project was limited to the AE study of the previously selected bridge crossing - the interstate I-664 bridge crossing over Terminal Ave. in Newport News, VA (southbound lanes) – to determine if there were any changes to the AE levels compared to the previous study. This highway bridge has VA Structure No. 2235, Federal Structure ID 0020750. As mentioned above, this bridge forms part of the Hampton Roads Beltway in the vicinity of the Monitor-Merrimac Memorial Bridge-Tunnel crossing, handles significant heavy truck traffic, and is located in the immediate proximity to the railroad serving the CSX Railroad Coal Loading Dock in Newport News, VA. Due to this as well as due to the interest exhibited by the VDOT/VCTIR personnel and the relative ease of access, installation, and maintenance of the AE equipment, this bridge was previously identified as an appropriate intermodal structure for the AE research. The bridge section under investigation utilizes the I-shaped steel girders with stiffeners and cross-frames as superstructure and supporting piers are constructed using the box-type steel cross girders with reinforced concrete columns as shown in Fig. 1 and 2.

Figure 1: General view of the I-664 bridge crossing over Terminal Ave. in Newport News, VA.

Figure 2: Close-up view of the girder to cross girder connection.

METHODOLOGY

The methodology of using the AE phenomenon that represents transient elastic waves produced by the rapid release of energy in a stressed material was utilized in this work. The AE transducers already attached to the bridge structure previously were re-used for current data measurements. In summary, the diagram below (Fig. 3) represents a general schematic of an AE monitoring system. Such system would include a transducer which detects the bursts of energy emitted by the source within the structure and a data acquisition hardware and software that receives, stores, and analyzes the AE data. The 16-channel Sensor Highway II (SHII) data acquisition system manufactured by the Mistras Group, Inc. was used for this work along with the PK15I 150 kHz 26 dB pre-amplified resonant AE sensors.

The literature review findings point to the following advantages and disadvantages of the AE approach for highway bridge applications. The advantages of the AE technology include the possibility of real time monitoring and continuous early flaw detection based on signal source location determination and high sensitivity to crack growth, minimization of traffic flow disturbances, and cost reductions. It can be applied to a variety of materials, such as metals, concrete, composites, etc. The disadvantages, however, include 1) lack of standardized methodology for such applications since each structure varies in terms of materials, geometry, and loads, which alters wave propagation modes and presents challenges in determination of a uniform and standard methodology, 2) the quantitative analysis of the data combined with the big volume of AE data obtained presents a problem with respect to effective and timely data analysis and ability to quantitatively assess the severity of the damage as opposed to qualitative assessments, and 3) the highway environment presents a noisy background for AE applications. However, the AE is still one of the most widely used non-destructive techniques used for bridge monitoring.

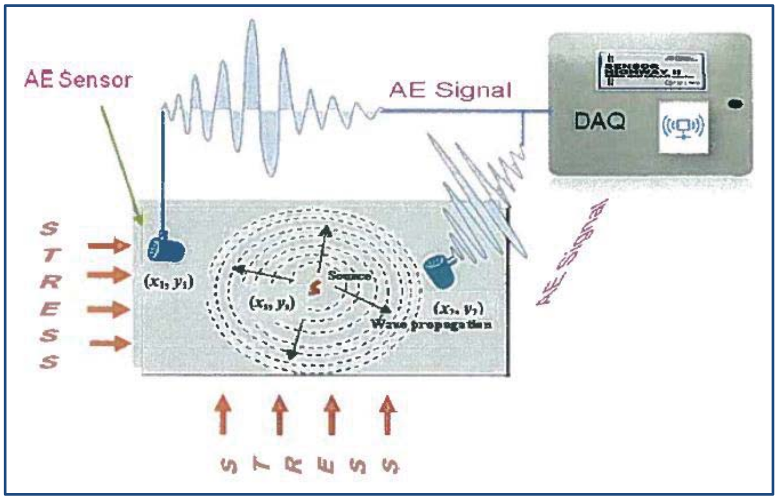

Figure 3: Schematic of the AE technology application.

The AE equipment setup was also completed in the same manner as previously. For more details on the AE methodology, equipment setup, sensors position, etc. please refer to the final report submitted to NCITEC in September 2015. The placement of AE transducers was selected previously to monitor the existing defect (a crack) that is located at the top end of one of the girders (#8) at its attachment to the cross girder (#6A/32SB). The diagram below (Fig. 4) illustrates the distribution of the AE sensors on the bridge girders. Two AE monitoring measurements were conducted during the month of May 2016 under similar loading and weather conditions for the same time interval and at the same AE hit threshold of 60 dB.

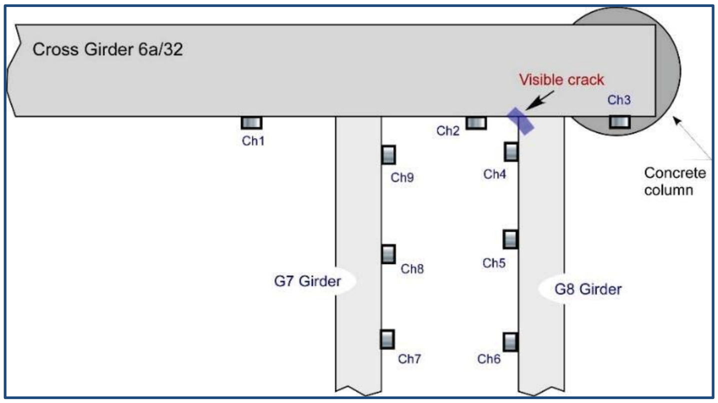

Figure 4: General layout of the AE sensors positions in relation to the crack location.

DISCUSSION OF RESULTS

Figures 5 through 12 below show the results of the current data acquisition in comparison to the previously recorded AE levels. In each figure, the left picture shows the most recent previous result acquired in summer 2015, while the middle and right pictures show the current measurements. It can be noted from these graphs that sensors 4, 5, 7, 8, and 9 captured the same or similar AE levels as previously, while sensors 1, 2, and 3 detected lower levels of AE activity which could be attributed to deteriorated surface contact between the transducer and the steel structure. In any case, comparison of these newly acquired AE levels to the previously recorded ones shows that there has been no appreciable increase in the AE activity in the vicinity of the known girder defect. Therefore, the absence of active

AE sources suggests that there is no active crack propagation occurring at this time - whether from the known single defect or from any newly formed cracks. The linear and two-dimensional location analyses conducted using the AEwin software also did not detect any AE sources corresponding to faults within the structure.

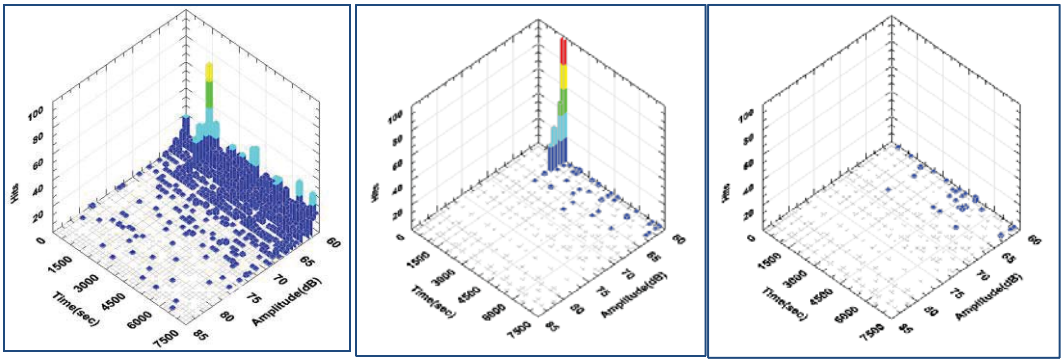

Fig. 5: AE activity observed at sensor 1 location.

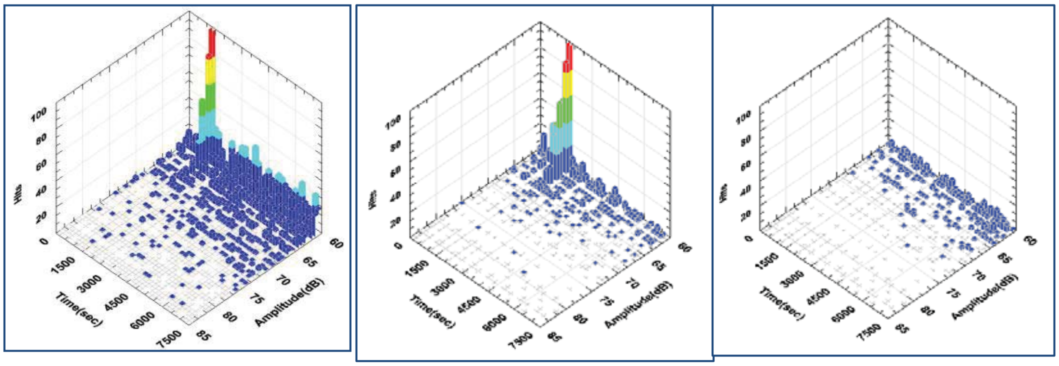

Fig. 6: AE activity observed at sensor 2 location.

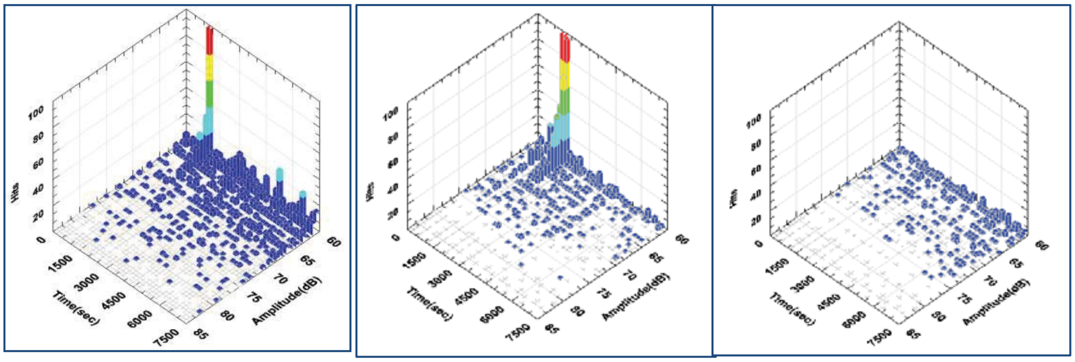

Fig. 7: AE activity observed at sensor 3 location.

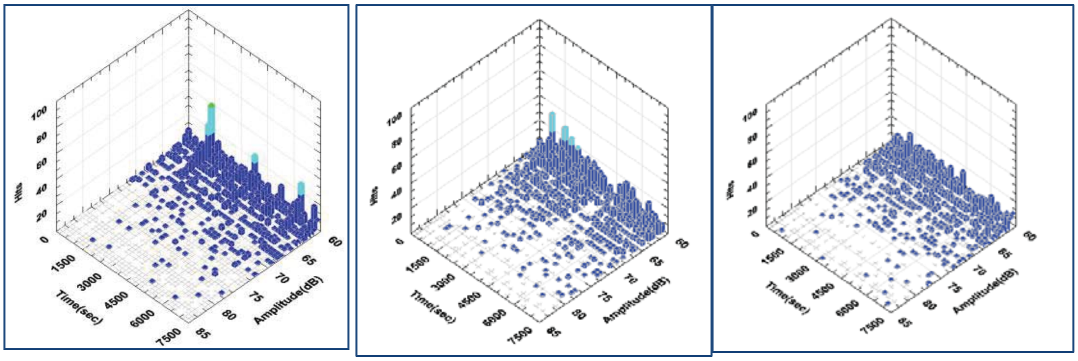

Fig. 8: AE activity observed at sensor 4 location.

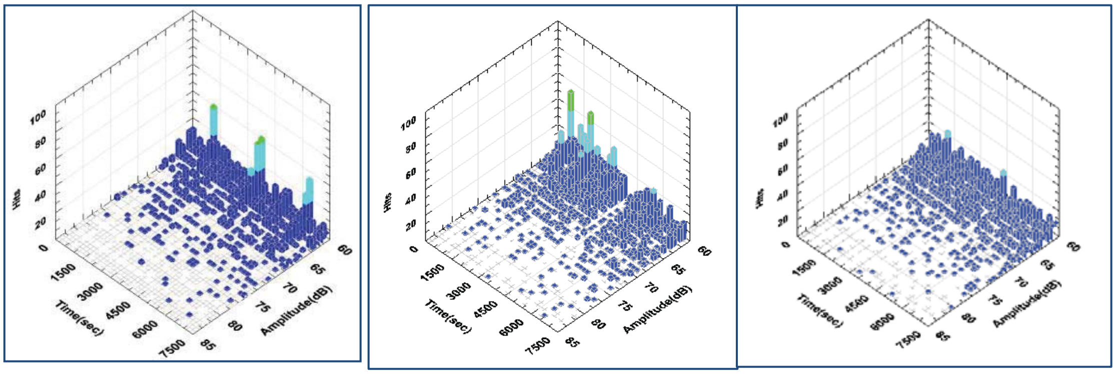

Fig. 9: AE activity observed at sensor 5 location.

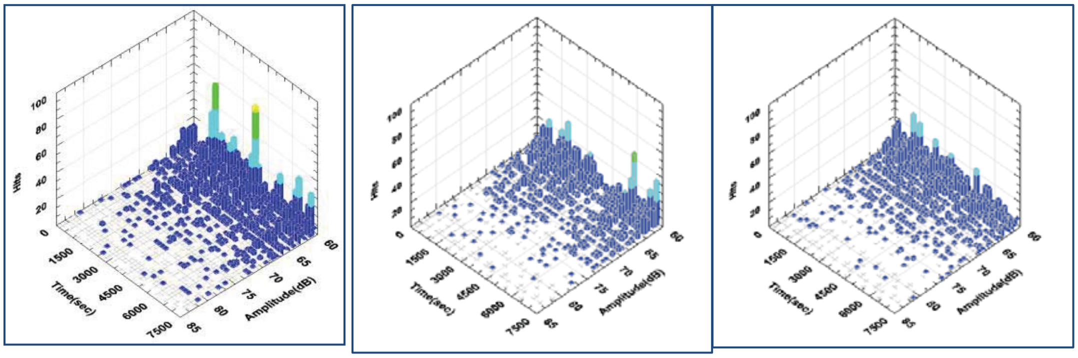

Fig. 10: AE activity observed at sensor 7 location.

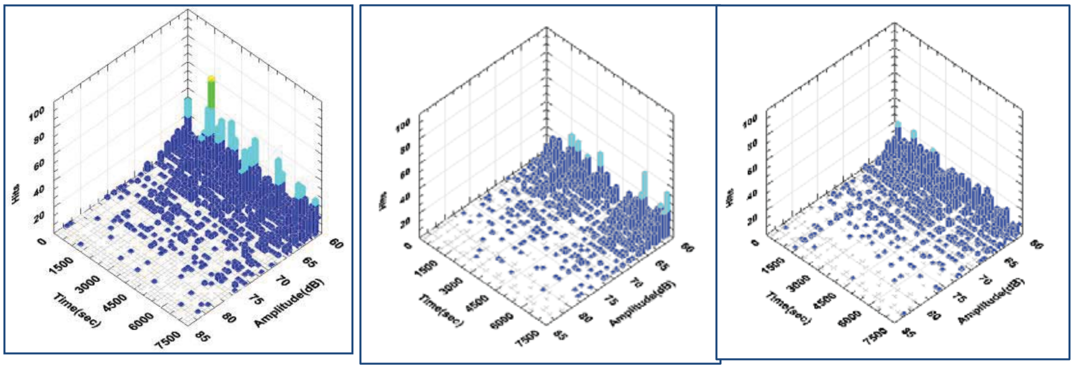

Fig. 11: AE activity observed at sensor 8 location.

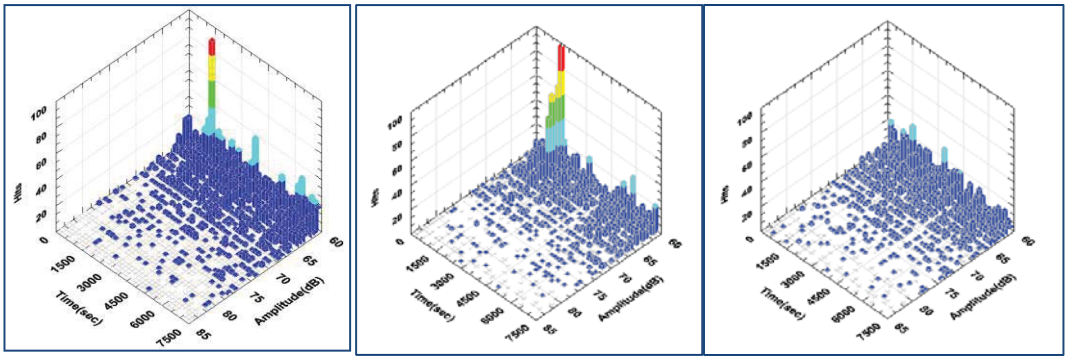

Fig. 12: AE activity observed at sensor 9 location.

CONCLUSIONS

The follow up analysis of AE activity in the affected location of the bridge structure did not show any signs of an active crack propagation. The level of AE activity measured corresponded to the previous AE activity level. The VDOT conducts periodical visual inspections of this girder, however, it is sometimes difficult to determine whether the crack actively propagates or stays arrested only by visual inspections and the AE technique can help to determine whether such cracks are active or not. Therefore, AE should be considered as a regular maintenance measure for economical early detection of possible structural failures.

This extended study also allowed upgrading the existing AE monitoring equipment with additional AE transducers. A low frequency R1.5I-AST 14 kHz resonance frequency sensor suitable for structural health monitoring of concrete and steel structures as well as the F50I-AST 200-800 kHz and two MICRO-30D 150-400 kHz wideband sensors appropriate for research applications where a high fidelity AE response is required were purchased to provide additional capabilities for the system for future use both in the field and within the HU lab setting for student training.

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

AE	Acoustic Emission
AEwin	Software for AE data acquisition and analysis
Ch	Channel
DAQ	Data Acquisition
dB	Decibel

HU	Hampton University
in	Inch
kHz	Kilohertz
NDT	Non-Destructive Testing
NCITEC	National Center for Intermodal Transportation for Economic Competitiveness
SHII	Sensor Highway II
VCTIR	Virginia Center for Transportation Innovation and Research
VDOT	Virginia Department of Transportation

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