Center for Transportation Infrastructure and Safety

Breaking Wire Detection and Strain Distribution of Seven-Wire Steel Cables with Acoustic Emission and Optical Fiber Sensors

by

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A National University Transportation Center at Missouri University of Science and Technology

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NUTC R305		

4. Title and Subtitle	5. Report Date
Breaking Wire Detection and Strain Distribution of Seven-Wire Steel Cables with Acoustic Emission and Optical Fiber Sensors	September 2013
	6. Performing Organization Code
7. Author/s	8. Performing Organization Report No.
Dr. Maochen Ge	Project # 00040017
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Center for Transportation Infrastructure and Safety/NUTC program Missouri University of Science and Technology 220 Engineering Research Lab Rolla, MO 65409	11. Contract or Grant No. DTRT06-G-0014
12. Sponsoring Organization Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Research and Innovative Technology Administration 1200 New Jersey Avenue, SE Washington, DC 20590	Final
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Cable-stayed bridges have been increasingly used as river-crossing links in highway and railway transportation networks. In the event of an abnormal situation, they can not only impact the local and national economy but also threaten the safety of passengers. To assess the structural condition of cables, the strain distribution among multiple wires must be effectively determined as one or more wires are broken due to overstress and/or corrosion. This proposal is focused on a preliminary study of wire breakage detection and associated strain redistribution. The specific objectives are to develop and validate a new algorithm for the localization of broken wires with acoustic emission technology and a new model for the determination of strain redistribution with distributed optical fiber sensor measurements. Both laboratory tests and numerical simulations will be conducted to understand the mechanism of strain redistribution as a result of wire breakage. In particular, a seven-wire steel cable will be tested and analyzed to take into account both the initial stress due to wire twisting and the friction effect between wires. For sensitivity study, various section losses in percentage of sectional area will be considered to understand the effective length of a cable over which the strain condition prior to the loss of wire sections can be recovered.

17. Key Words	18. Distribution Statement
Bridge engineering, cable stays, condition assessment, seven-wire cable	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. Of Pages	22. Price
unclassified	unclassified	7	

Form DOT F 1700.7 (8-72)

Breaking Wire Detection and Strain Distribution of Seven-Wire Steel Cables with Acoustic Emission and Optical Fiber Sensors

Final Technical report

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September 25, 2013

1. Introduction

Cable-stayed bridges have been increasingly used as river-crossing links in highway and railway transportation networks. In the event of an abnormal situation, they can not only impact the local and national economy but also threaten the safety of passengers. To assess the structural condition of cables, the strain distribution among multiple wires must be effectively determined as one or more wires are broken due to overstress and/or corrosion.

This proposal is focused on a preliminary study of wire breakage detection and associated strain redistribution. The specific objectives are to develop and validate a new algorithm for the localization of broken wires with acoustic emission technology and a new model for the determination of strain redistribution with distributed optical fiber sensor measurements.

The intent of this study is to provide the interdisciplinary team with a unique opportunity to initiate a new research direction, collect preliminary data, and establish a good track record for collaborative work on the proposed topic.

This research is collaboration between two teams lead by Dr. Ganda Chen from Civil Engineering and Dr. Maochen Ge from Mining and Nuclear Engineering. The focus of Dr. Maochen Ge's team is analysis of acoustic emission (AE) data obtained from the laboratory tests and development a suitable algorithm for locating the recorded AE events. Dr. Ge's team includes Dr. Ge and Mr. Ibrahim Ahmed, a graduate student of Mining and Nuclear Engineering.

2. Student Training

The research on acoustic emission at Missouri University of Science and Technology was new and the graduate students in the university community did not exposed to this topic prior to the current study. To prepare the graduate student for this study, Dr. Ge developed an AE study program for Mr. Ibrahim Ahmed. Partially because of this effort, a 3-credit graduate course on acoustic emission was developed and offered in Fall 2013.

3. Development of the location algorithm for steel cables

The AE source location on steel cables depends on many factors. There are two main concerns. One is how to install the sensor which would most effectively pick up the AE signals. The second one is the strength of the AE signals as cable wires serve as a wave guide. In order to deal with this complicated situation, we plan to use three mechanisms for source location: 1) P-wave arrival time difference, 2) P- and S-wave arrival time difference, and 3) signal magnitude. We plan to develop a "smart" algorithm based on the characteristics of the test data.

3. Laboratory test

A multichannel AE system (Figures 1 and 2) was purchased from Mistras Group Inc., located in Princeton Junction NJ. The company provided one day training course about the system, which covered both the hardware and software.

The training on software concentrated on the data acquisition by using AEwin software to detect AE signals. Figure 3 is such an example. The software has the capability of advanced graphing, location, waveform processing, remote monitoring and filtering.

After the initial training, the graduate students of this project (two graduate students from Civil Engineering Department and one graduate student from Mining & Nuclear Engineering Department) met regularly on monthly basis to discuss both hardware and software operational issues.

Because of the delayed delivering of the AE system, no laboratory tests were conducted at the time of filing this report.

Figure 1: Multichannel AE Systems

Figure 2: Sensors

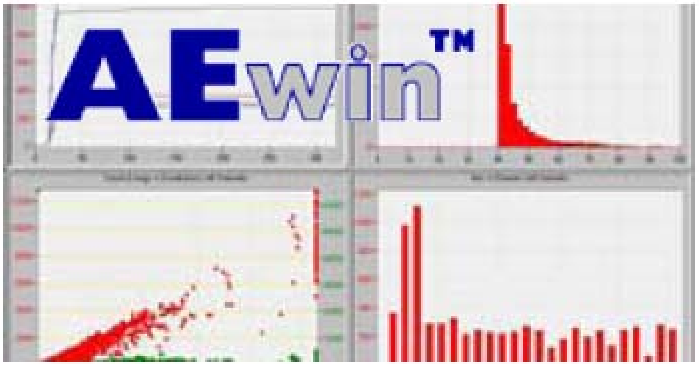

Figure 3: AEwin is real-time operating software.