Remote Health Monitoring of a High Performance Steel Bridge using Fiber Optic Technology

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INTRODUCTION

In early 2004, the Iowa Department of Transportation (DOT) completed construction of Iowa's first High Performance Steel (HPS) bridge through the Federal Highway Administration's (FHWA) Innovative Bridge Research and Construction (IBRC) program. When compared with conventional steels, HPS has improved weldability, weathering capabilities, and fracture toughness.

In cooperation with the Office of Bridges and Structures at the Iowa DOT, the Bridge Engineering Center at Iowa State University has developed a continuous Structural Health-Monitoring (SHM) system to monitor and record the performance of the HPS bridge for a two-year period. With this system, the bridge performance can be evaluated at any point in time as well as with respect to time.

BRIDGE DESCRIPTION

The East 12th Street bridge over I-235 in Des Moines, IA, is a 298 ft - 6 in. continuous two-span HPS girder bridge with a cast-in-place concrete deck and integral abutments. Six girders, transversely spaced at approximately 8 ft – 8 in., utilize HPS 50W and 70W in the positive and negative moment regions, respectively. The two-lane bridge, which is approximately 50 ft – 3 in. wide, features pedestrian walkways on both outside edges of the bridge.

OBJECTIVES

The main objectives of the monitoring and evaluation portion of this project include:

- Continuously evaluate local and global bridge structural performance,
- Monitor the bridge over time to develop a baseline record for identifying structural performance changes, and
- Conduct a detailed fatigue evaluation

By using the SHM system to continuously monitor local and global bridge behavior, at any point in time, the overall condition of the bridge can be evaluated. Moreover, the technology configured in this project could provide the required information to predict bridge deterioration over time, and thus, provide an opportunity to predict the remaining life of a structure by knowing current characteristics of the bridge. Finally, the long-term performance of several typical and atypical fatigue sensitive details is being evaluated; examples of these details include web gap regions, stiffeners welded to the tension flange, and weld concentrations at web and flange splices.

SHM SYSTEM CONFIGURATION

The HPS bridge SHM system consists of components developed from several different manufacturers. When possible, standard off-the-shelf components were utilized to maintain minimum cost for the system. The primary components of the SHM system are as follows:

- Strain Sensing Equipment
  - Si425-500 Interrogator, developed by Micron Optics, Inc.
  - 30 Fiber Bragg Grating (FBG) Sensors
- Video Equipment
  - Network Video Camera

- Networking Components
  - DSL Modem with Internet Service
    (Transfer Rates = 1.5 MBps [download], 1.0 MBps [upload])
  - 2.4 GHz Wireless-802.11g Router
  - 2.4 GHz Wireless-802.11g Access Points
- Data Management Equipment
  - Data Collection Server
    (Desktop Computer - 450 MHz Processor, 8.0 GB Hard Drive, 256 MB RAM)
  - Web Server
    (Desktop Computer - 700 MHz Processor, 20.0 GB Hard Drive, 256 MB RAM)
  - Data Storage Server
    (Server - 3.0 GHz Processor, 1.2 TB Hard drive, 4.0 GB RAM)

The SHM system primary components can be divided into three major sub-systems, as shown schematically in Fig. 1. The Data Acquisition Sub-system (Fig. 2), located at the bridge pier, collects and transfers data via

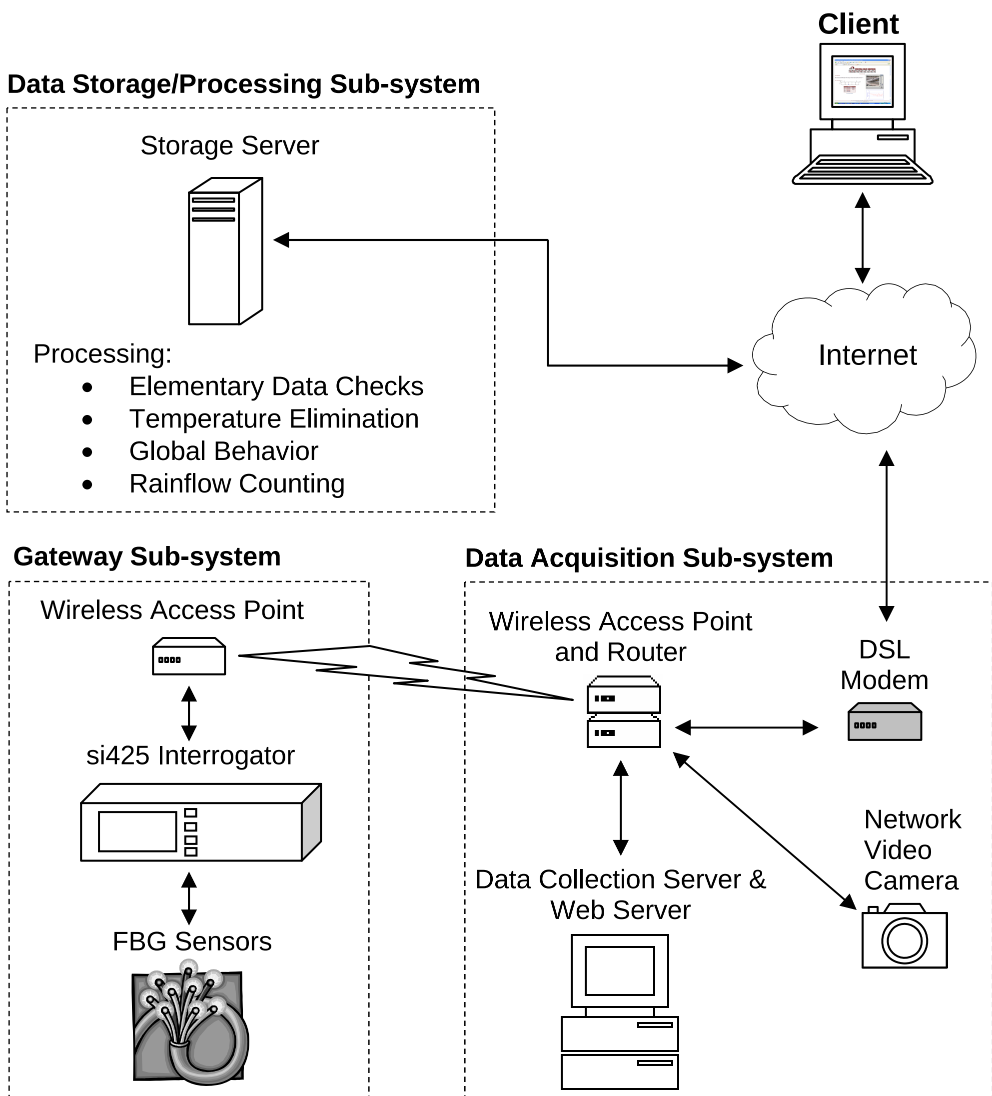
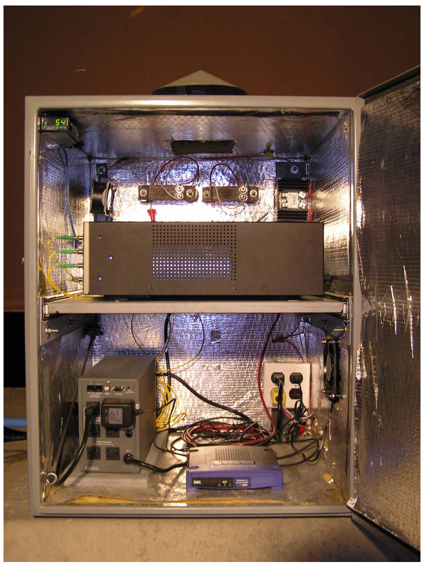


Figure 1. Flow Diagram of East 12th St. Bridge Health Monitoring System.

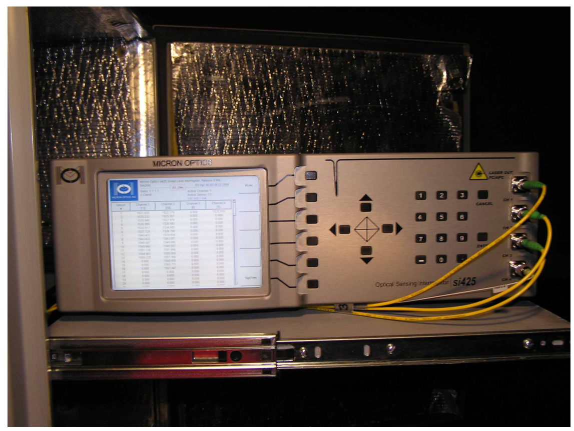
wireless communication to the Gateway Sub-system (Fig. 3), which is located in a secure facility adjacent to the bridge. The Gateway Sub-system uploads the strain data to the internet where it can be viewed from anywhere in the world in real time (http://www.ctre.iastate.edu/bec/structural_health/hps/index.htm) while it simultaneously compresses and temporarily stores the strain data. The data packets are automatically retrieved by the Data Storage Sub-system at the Bridge Engineering Center at Iowa State University.

DATA PROCESSING

After the data are received at the Bridge Engineering Center, several steps are performed which ensure that the entire system is operating properly, eliminate temperature strain from the complete strain record, monitor the global behavior of the bridge, and count stress cycles induced on the localized details. Figure 4 illustrates typical data collected for one week at one sensor location.



a. Hardware Stored in the Environmentally Controlled Protective Box at the Bridge Pier



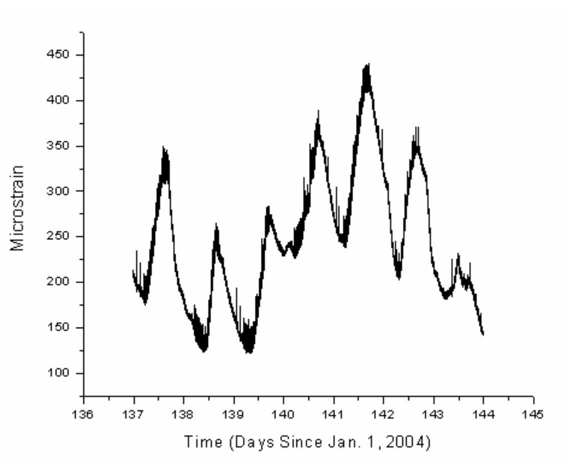
b. The Micron Optics si425-500 Optical Interrogator

d. Two FBG Sensors for Monitoring Localized Weld Strains

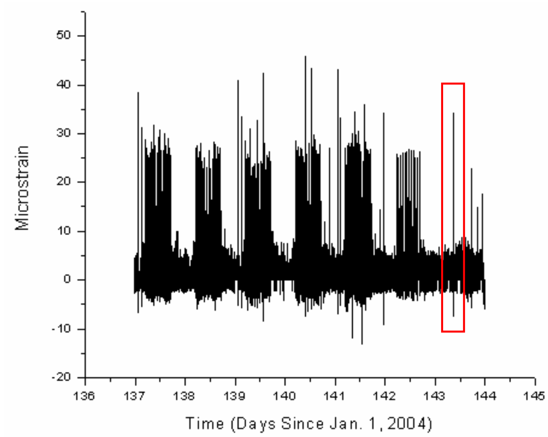
d. Antennas for the Wireless Access Point

Figure 2. Photographs of the Data Acquisition Sub-system Components.

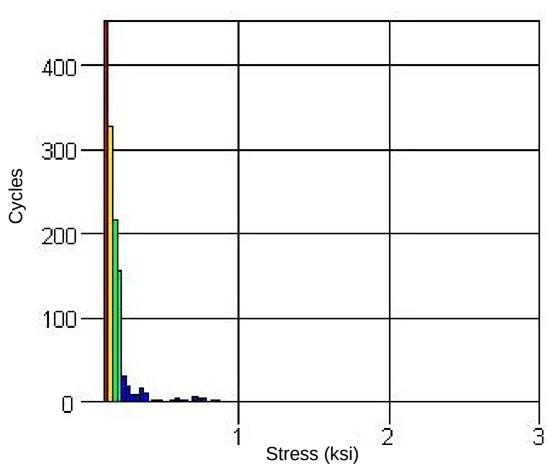
Figure 3. Photograph of Gateway Sub-system Hardware.



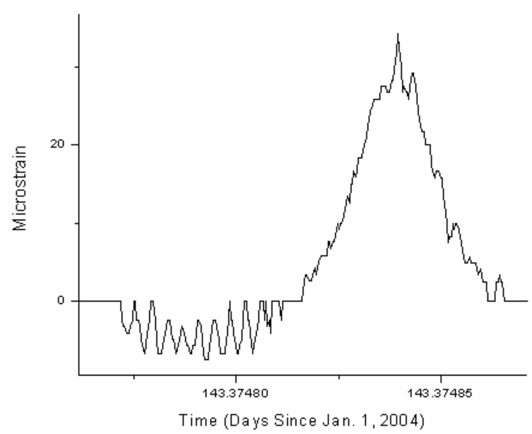
a. Raw Data for One Week



b. Temperature-Corrected Data for One Week



c. Stress Cycles for One Week



d. Traffic Event Indicated in Fig. 4b

Figure 4. Typical Collected Strain Data – Bottom Flange of Girder.

A method for summarizing the daily, weekly, and monthly performance of the bridge is also being developed. These brief reports will be automatically generated to give the bridge owner an overview of the bridge condition and performance.

CONCLUSION

With the SHM system in place on the East 12th St. Bridge over I-235 in Des Moines, a significant step has been made in the ability to effectively (both in terms of information collected and cost) monitor and evaluate structures continuously from a remote location. The system allows the client to view real-time video of traffic crossing the bridge and the corresponding real-time strain data at various bridge locations.

For more information regarding the E. 12th Street SHM system, contact:

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