Development of a Self-Sustained Wireless Integrated Structural Health Monitoring System for Highway Bridges

University of Maryland with North Carolina State University and URS

Executive Summary

Fatigue-induced cracking is a common failure mode in many steel bridges reaching their original design life. These aging bridge structures have experienced increasing traffic volume and weight, deteriorating components as well as a large number of stress cycles. Despite years of research in overcoming these challenges, catastrophic failures (e.g., the interstate 35W bridge collapse in Minneapolis, MN in 2007) still occur, which is mainly due to various difficulties in detecting bridge health conditions under highly uncertain operational conditions and also our limited understanding of the failure mechanisms in these systems. This project strives to address this issue by establishing an Integrated Structural Health Monitoring (ISHM) System for remote infrastructure sensing, diagnostics and prognosis. The ISHM entailed a few recent innovations that transformed the current state-of-the-practice in remote sensing and management of highway infrastructures.

The novelty and uniqueness of the technologies of this project are summarized into the following five thrust areas:
Thrust 1: Reconfigurable sensor dots (sensor technology)
Thrust 2: Passive interrogation of evolving damage (AE diagnostics)
Thrust 3: Hybrid-mode energy scavenger (energy harvesting) to power wireless sensor
Thrust 4: Multi-media wireless smart sensor (Wireless sensing)
Thrust 5: Prognostics

Findings & Outputs

Based on the five thrust areas, there are six tasks involved in this project, which are:
Task 1: Establishing weak point identification maps and conducting baseline field tests
Task 2: Fabrication and characterization of piezo paint AE sensor with reconfigurable sensing dots
Task 3: Development of a time-reversal (T-R) method for AE source identification
Task 4: Development of a wireless smart sensor with a hybrid-mode energy harvester and embedded T-R algorithms
Task 5: Developing ISHM in both laboratory and field environments and implementation with Bridge Management System
Task 6: Project Website, Report and Project Assessment

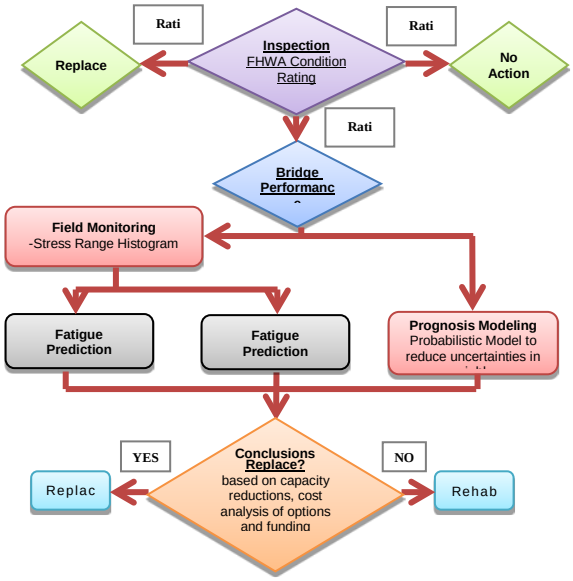
Findings by tasks are listed here:
1. All activities under Task 1 (finite element model, sensor placement scheme, environmental variable data, etc.) were all accomplished timely.
2. All activities under Task 2 (piezo paint sensor with improved sensitivity, reconfigurable piezo paint sensor dots) were all accomplished timely.
3. All activities under Tasks 3 and 4 (onboard diagnostics method based on the T-R algorithm, self-sustained wireless smart sensor and hybrid-mode energy harvester) were completed in the extended third year.
4. All activities in lab tests and field tests of the ISHM system under Task 5 (integrated piezo paint AE sensors with wireless smart sensor and hybrid-mode energy harvester) were completed in the extended third year.
5. Finding of strategy to incorporate remote sensing and prognosis of bridge components into bridge management system under Task 5.3 were considered and reported.

Products & Outcomes

In summary, a functioning wireless Integrated Structural Health Monitoring (ISHM) System with remote sensing, diagnostics and prognosis was developed, tested in the lab as well as in the field, deployed and validate.

Wireless AE Sensor (Left) and Crack (Right)

The ISHM system is a sensor driven approach which yields multi-dimensional information about the reliability evolution of the monitored bridge structure in future operation years.



Flowchart to illustrate improved application of condition ratings

Post Project Initiatives

Guests from the Maryland Department of Transportation were invited to the demo site at I-95 over Patuxent River, Laurel, MD. The whole process was performed to showcase the wireless smart sensor system with piezo paint AE sensors and hybrid-mode energy harvester. Also demonstrated were the pencil break tests to simulate the fatigue cracks to different groups of guests from Maryland State Highway Administration (MDSHA) and Maryland Transportation Authority (MDTA) to demonstrate the AE sensor and crack detection technology and explain the benefits of the system to the bridge owners. It was a very successful event.

Guests from the MD State DOT

The UMD research team met with the staff members from the Office of Technology Commercialization (OTC) of the University of Maryland. During the meeting, the UMD research team presented the project research work/outcomes and potential sensor and crack detection technologies for licensing. The OTC demonstrated the procedure for technology licensing and encouraged the project team to discuss with potential technology transfer partners for licensing. Strategy of commercialization has been consulted to the Offices of Technology Commercialization (OTC) of UMD and NCSU, and other DOTs.

I-95 Bridge site and the solar-wind Hybridge power

CONTACTS:

U.S. Department of Transportation (US DOT)
Caesar Singh, P.E.
Director, University Grants Programs
Office of the Assistant Secretary for Research and Technology (OST-R)
1200 New Jersey Avenue, E33-306
Washington DC 20590
Tele: 202/366-3252
Email: Caesar.singh@dot.gov

University Name
Chung C. Fu, Ph.D., P.E., Director/Research
Professor, BEST Center, UMD
Address – CEE Department
University of Maryland
College Park, MD 20742
Tele: - (301) 405-2011
Email: ccfu@umd.edu