# Multi-modal Remote Sensing System (MRSS) for Transportation Infrastructure Inspection and Monitoring
## University of Massachusetts Lowell

### Executive Summary

Managing the growing population of deteriorated transportation infrastructure systems (i.e. highway bridges) and being able to accurately inspect them in a timely and cost effective manner is a major societal challenge within the U.S. today. Traditional nondestructive testing/inspection/evaluation (NDT/NDI/ NDE) methods for highway bridges cannot currently provide an accurate and rapid evaluation (independent of human biases and interpretation) on a routine basis to prevent deteriorated bridges from sudden collapse. Automated, low-cost, efficient bridge inspection techniques for interrogating critical bridge components are needed. Existing highway bridge inspection techniques are typically time consuming, labor intensive, and cost inefficient. Safety issue, interference with existing traffic, and subjective evaluation of visual inspection are additional disadvantages in such inspections.

The objective of this project is to develop a multi-modal remote sensing system (MRSS) that will be used as the next generation of rapid, distant, interrogation technology for bridge inspection. The proposed MRSS combines advantages of NDT (local inspection) and structural health monitoring (SHM) (global, continuous monitoring), using innovative continuous wave imaging radar (CWIR), digital image correlation (DIC), and fiber optic sensors (FOS) to deliver a cost-effective, robust solution for the inspection and monitoring of critical transportation infrastructure such as highway bridges. MRSS represents the next-generation of portable bridge inspection technology for efficient inspection, evaluation and rating of bridges.

(a) Collapsed I-70 Lake View Drive Bridge, Pittsburgh, PA
(b) Corrosion of the bridge
**Fig. 1** Failures of highways bridges

### Findings & Outputs

From our laboratory and field activities, research findings are summarized.

- CWIR can identify the type of materials in both distant laboratory and distant field measurement schemes. CWIR can also identify and locate a #3 subsurface rebar inside concrete at a concrete cover of 3" from distant measurement.
- Background noise (electromagnetic) does not affect the performance of CWIR when conducting distant measurements within 100 ft. Detectability of CWIR is not jeopardized by background noise in the field when signal-to-noise ratio (SNR) is higher than 1.5~2 in various applications. Denoising techniques are helpful in improving the detectability of CWIR in field applications.

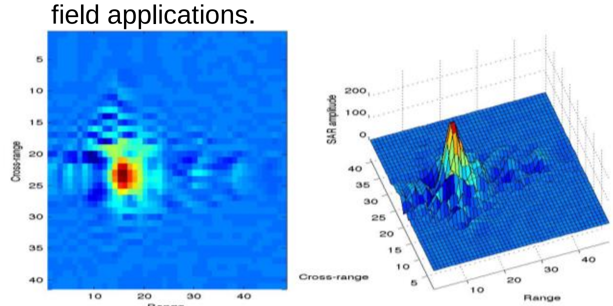
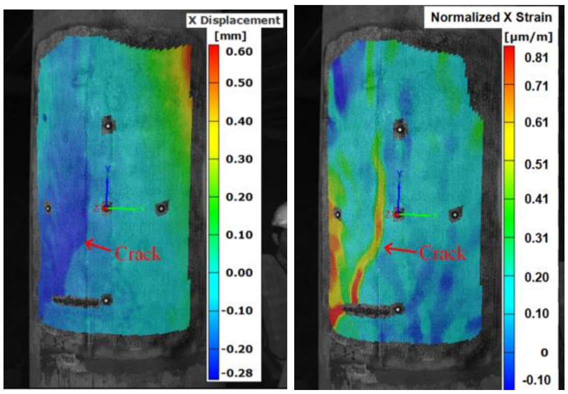



**Fig. 2** Subsurface CWIR imaging of a RC cylinder

- DIC is capable of monitoring the long-term displacement and reconstructing the surface stress/strain fields of reinforced concrete (RC) highway bridges, from our 9-month field measurements. Using surface stress distribution, DIC can also indicate possible cracking areas of RC bridge elements, even though there is no visible surface cracking of concrete.
- Calibration and pattern deployment are important to the performance of DIC. Various pattern deployment schemes (e.g., physical painting, optical laser projecting) were investigated and tested. Optical laser projecting scheme is applicable and uses only few reference marks on the surface of structures.
- Laboratory and field FOS measurements show good agreement with the DIC result, suggesting the robustness of DIC.

- Multi-modal laboratory RC beam tests using CWIR, DIC, and FOS demonstrated a consistent, repeatable coupling pattern between the electromagnetic (CWIR) and mechanical responses of a RC beam. The local mechanical response (stress/strain) of a RC beam can be related to the global behavior of the beam




(a) X-axis displacement (b) Normalized x strain
**Fig. 3** Displ. and strain of a RC highway bridge pier

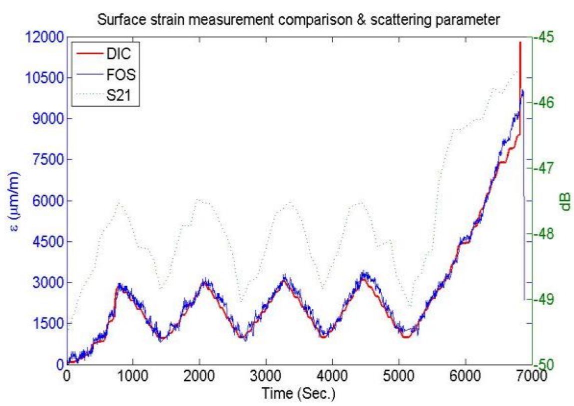



**Fig. 4** Coupling of CWIR, DIC and FOS measurements of a laboratory RC beam under cyclic loading

**Products & Outcomes**

Developed products from the MRSS project mainly include a portable CWIR/DIC system, a User's Manual, laboratory and field test reports of MRSS, numerical simulation reports (radar signal propagation), and CWIR software. We are also working with MassHighway (MassDOT) on applying our system to few selected damaged RC highway bridges.

(a) Portable CWIR (b) Portable DIC
**Fig. 5** Portable MRSS hardware

**Post Project Initiatives**

We are in the process of applying for one or two patents (one for CWIR concept, one for mechanical/ electromagnetic coupling) incurred from the project. We have worked with Trilion Quality Systems in commercializing the portable DIC system as a product (now available in the market), and we are also working with the Office of CVIP (Commercial Ventures & Intellectual Property) at UMass Lowell to convert the third generation of CWIR into a commercial product (fourth generation).

**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, E35-306
Washington DC 20590
Tele: 202/366-3252
Email: Caesar.singh@dot.gov

**University Name**
Dr. Tzuyang Yu, Associate Professor
Civil & Environ. Engrg.
The University of Massachusetts Lowell
Falmouth 107C
One University Avenue
Lowell, MA 01854-2827
Tele: (978) 934-2288
Email: tzuyang_yu@uml.edu