Integration of Self-Sustained Wireless Structural Health-Monitoring System for Highway Bridges

by

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Public Abstract

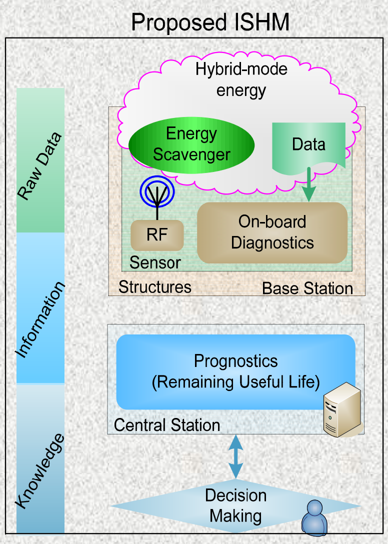
- Develop a self-sustained Integrated Structural Health Monitoring (ISHM) system with *remote sensing capability*
- Holds promise of system *scalability* and *autonomousness* in remote monitoring *large complex* highway infrastructures.
- Particularly suited for fatigue condition assessment of highway steel bridges
- With a potential to extend to evaluate other types of bridge damages, such as breaks and corrosion of steel strands of pre-stressed concrete bridges.

Comparison

Architecture of ISHM for Remote Sensing

Impact to remote sensing practice

- **Innovative, autonomous, self-sustained, scalable**
- **Ready for field validation**
- **Improving current bridge inspection and monitoring practices**



Merits of the ISHM System

Thrust 1 - (Sensor technology) Flexible piezo paint sensor dot array

Thrust 2 - (AE diagnostics) Passive interrogation of evolving damage

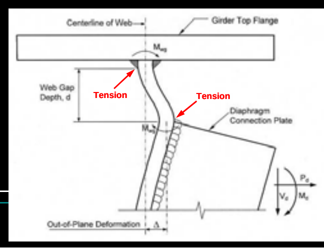
Thrust 3 - (Energy scavenging) Hybrid-mode energy scavenger

Thrust 4 - (Wireless sensing) Wireless smart sensor

Thrust 5 - (Prognostics) Prognostics using Bayesian updating and continuous remote sensing data

Distortion Induced Fatigue

Δσ is secondary stress due to LL induced local distortion. Depending on detailing of primary /secondary connections.

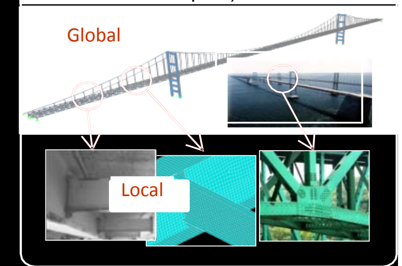


Project Planning and Preliminaries

- Deliverables:
  - Formed Technical Advisory Committee (TAC) and conduct kick-off meeting.
  - Determined baseline field test procedure
  - Established and updating project web site
  - Conducted baseline field test and finite element analysis on pre-selected bridges

Table 1.1: Potential Failure Maps

(Global/local FE approach to identify hot spots)



Potential Failure Map through FEM Analysis

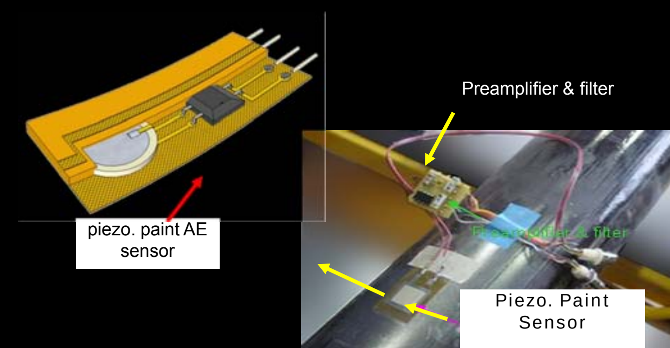
Thrust 1: Piezo Paint AE sensor

Advantages:

- Tunable bandwidth
- Reconfigurable sensor dots
- Conformable to complex geometry or curved surface
- Application to large area
- Low profile
- Low cost

Piezo Paint AE Sensor Deliverables

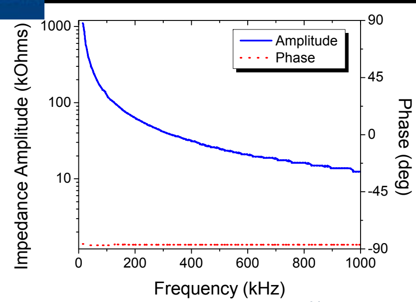
- Deliverables:
  - Design, fabricate and characterize piezo paint AE sensor and measure the performance



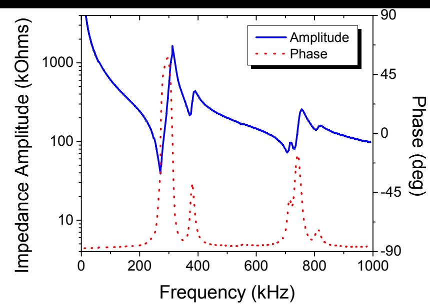
Flexible piezoelectric paint sensor tested in the UMD laboratory

Piezoelectric Paint AE Sensor with Broad Bandwidth

- Piezo paint AE sensors have non-resonance characteristics in general.
- All signals will be received with more or less equal sensitivity over a wide range of frequency.
- High fidelity signal measurement because of its wideband feature enables advanced waveform-based signal interpretation for structural damage detection

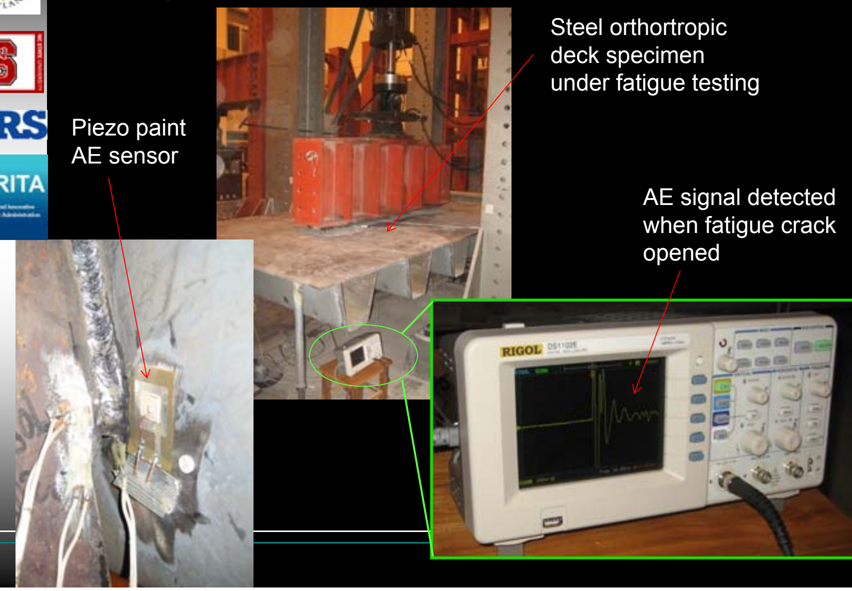


Piezoelectric paint with 45% volume fraction of PZT powder, 0.63-mm thickness

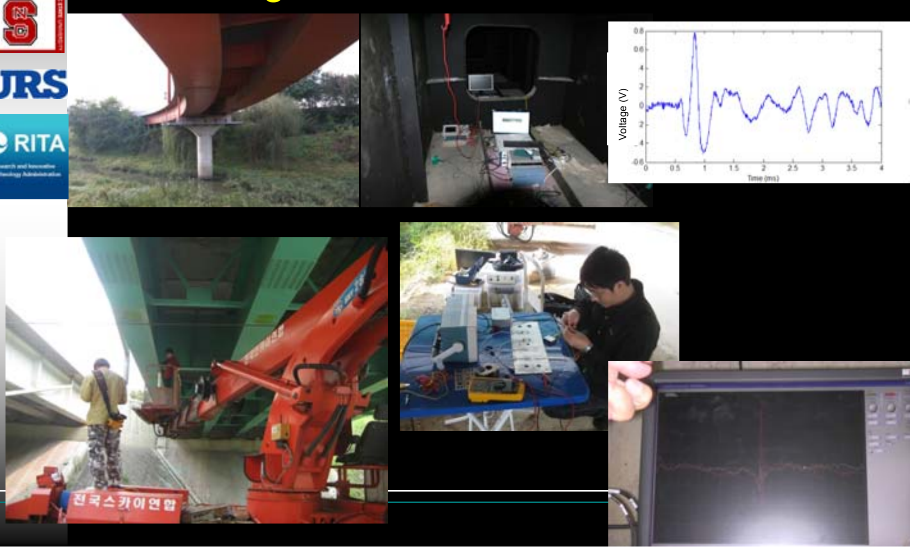


PZT patch with a 0.2-mm thickness

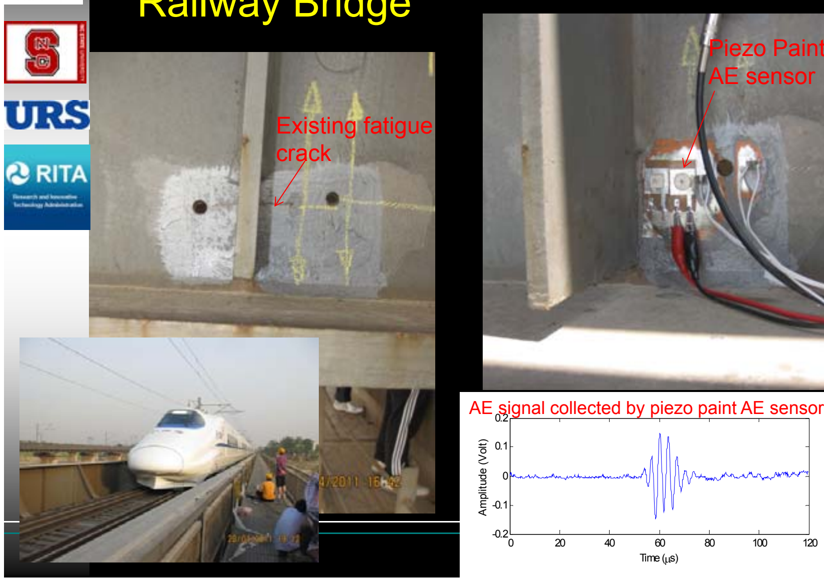
Fatigue test of Steel Orthotropic Deck



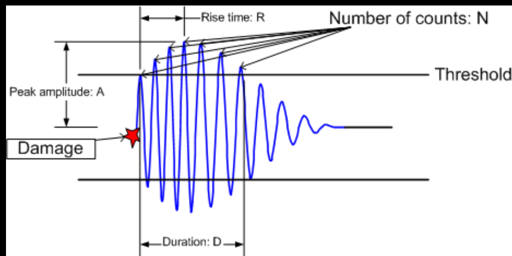
Field Tests of Piezo Paint AE Sensor on Two Steel Bridges in Korea



Field Test of Piezo Paint AE Sensor on a Railway Bridge



Current AE Analysis (Signal-based)



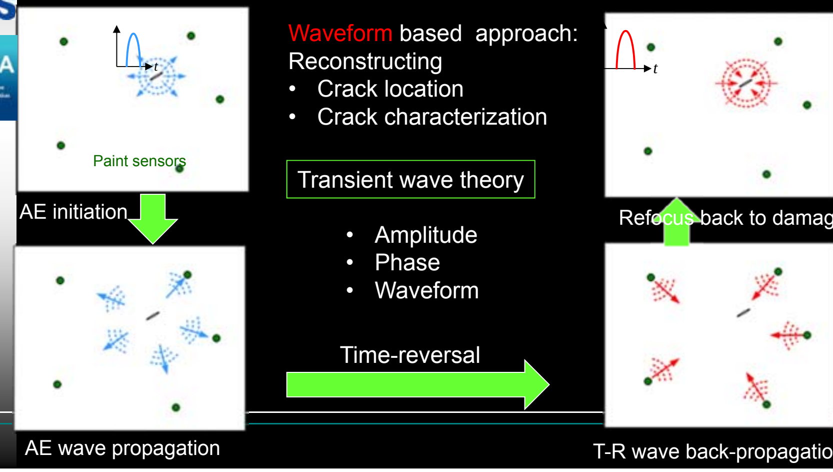
Conventional signal-based approach:

- AE parameter analysis
- AE activity analysis
- AE frequency analysis

Need physics-based approach!

Thrust 2: Time-Reversal (T-R) Method for AE Source Identification

- Develop and evaluate TR method for continual passive damage interrogation



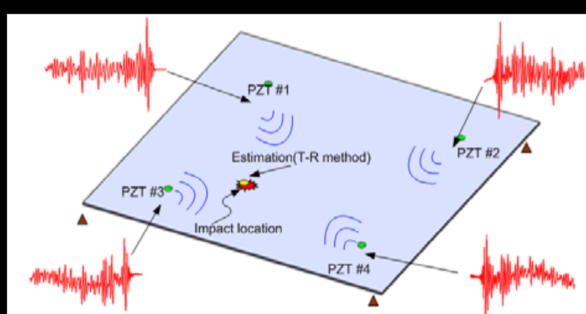
Waveform based approach:
Reconstructing
- Crack location
- Crack characterization

Transient wave theory

- Amplitude
- Phase
- Waveform

Time-reversal

Preliminary Verification of T-R Method

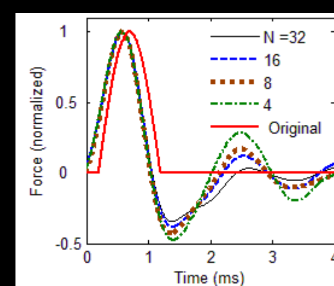


Actual location: (-76,-46) mm
Estimated location: (-80,-40) mm

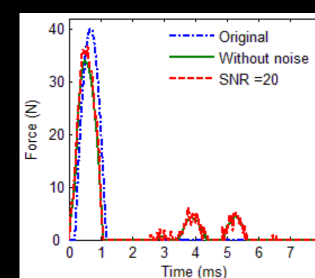
1.6% error in 420×420mm plate

C. L. Chen and F. G. Yuan, "Impact Source Identification of Isotropic Plate Structures using Time-Reversal Method: Theoretical Study," *Smart Materials and Structures*, Vol. 19, 105028, 2010.

Preliminary Verification of Impulse Characterization



Effect of number of sensors

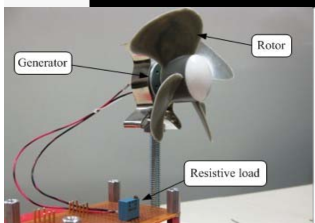


Effect of Noise

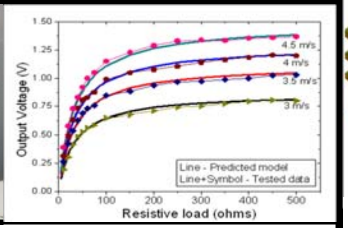
C. L. Chen and F. G. Yuan, "Impact Source Identification of Isotropic Plate Structures using Time-Reversal Method: Theoretical Study" *Smart Materials and Structures*, Vol. 19, 105028, 2010.

Thrust 3: Hybrid-mode energy scavenger & Thrust 4: Wireless smart sensor

- Deliverables:
  - Develop and experimentally evaluate wireless smart sensor and hybrid-mode energy harvester
  - Implement passive damage interrogation T-R algorithm in the wireless smart sensor on



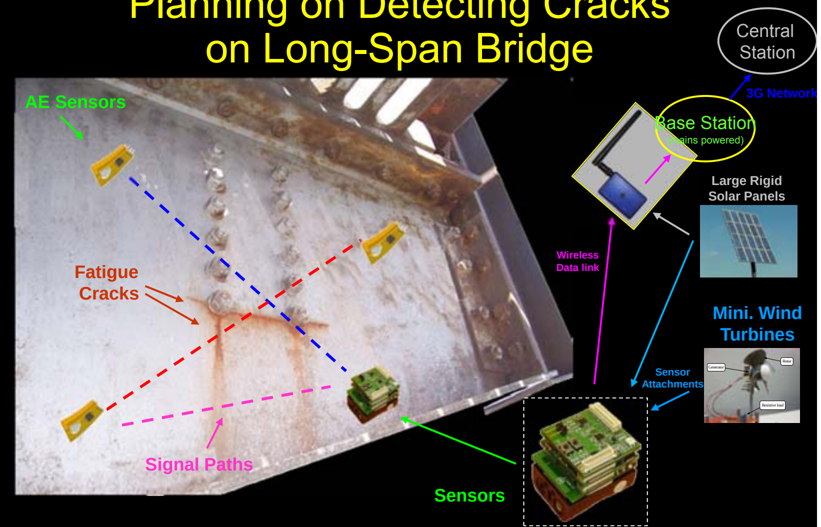
Miniature Wind Turbine system developed by NCSU to harvest wind energy



Tested and predicted output voltage versus resistive load

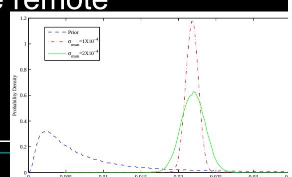
A compact modularized high speed wireless sensor platform developed by NCSU researchers.

Planning on Detecting Cracks on Long-Span Bridge



Thrust 5: Prognostics using Bayesian Updating

- Deliverables:
  - Integrate and validate AE sensors with wireless smart sensor and hybrid-mode energy harvester
  - Develop and conduct field implementation/validation of commercial-ready ISHM system with remote sensing capability
  - Recommend strategy to incorporate remote sensing and prognosis into BMS



Benefits and the Potential Impact

- A cost-effective remote infrastructure sensing/monitoring system
- Expected to be commercialized and incorporated into the nation’s infrastructure system
- Improved performance will benefit both the DOTs and general public in ensuring the safety and lowering the maintenance costs
- Technology transfer and commercialization of the new technologies developed in this project.

Thanks!