

Vision for the Multi-Function Dynamics Laboratory

Structural Health Evaluation

Elizabeth K. Ervin

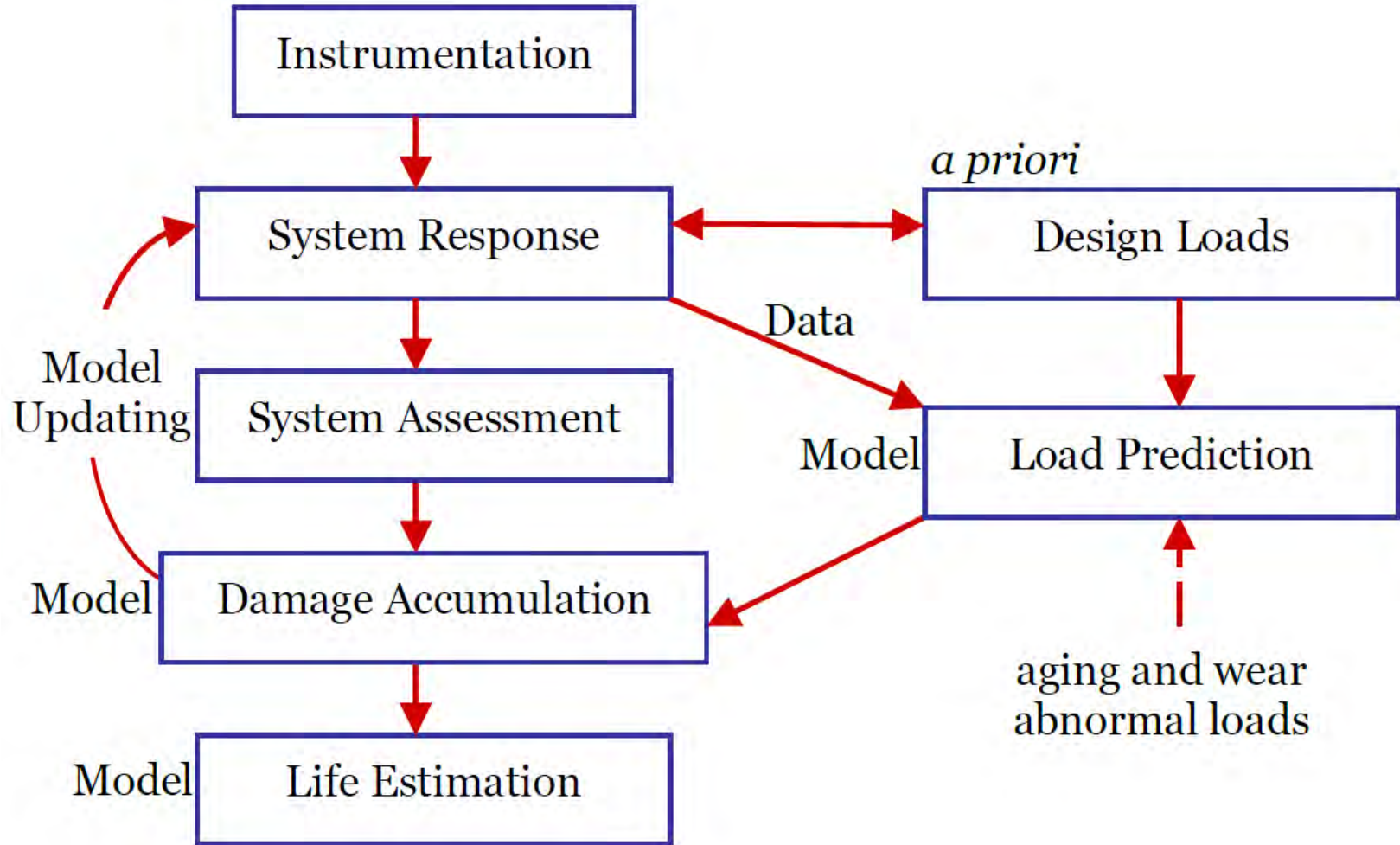
TEACH
encourage
instruct
MENTOR
PRAISE
influence
GUIDE
INSPIRE



CE



Repair, Rehabilitate, Raze, or Replace ?



Breaking News... 9/26/13

- Call to Wisconsin 911: *“There’s a dip in the bridge!”*
- One pier sunk two feet into the ground overnight.

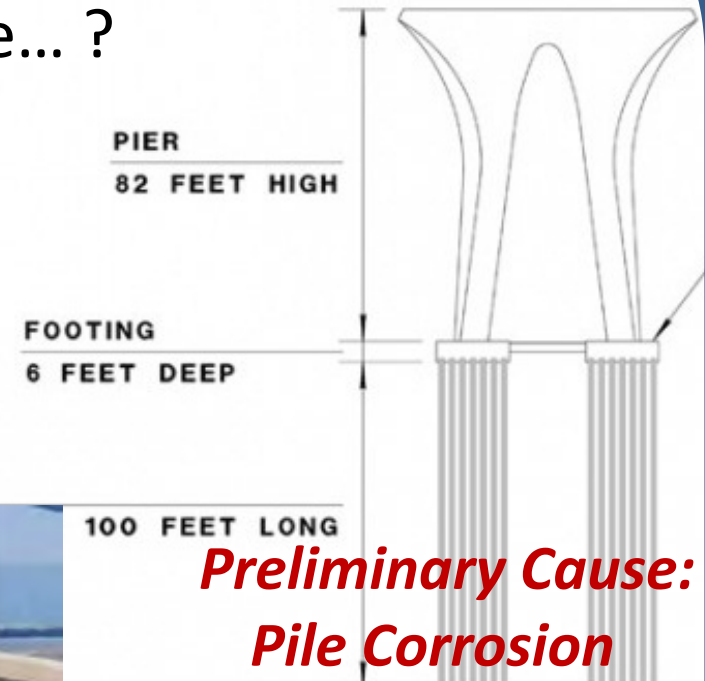


Frigo Bridge: built in 1980, last inspected August 2012

Motivation

Could this have been detected before... ?

- endangering public safety
- generating extended road closure
- causing extensive repair



Pier 22

Eastgate Bridge

*Completed in 1940 by MDOT.
(34' tall, 160' long, 4-lane on skew)*

*Heavily used central connector by
the Circle/Grove, and Ford Center.*

*Discovered no claimed owner –
regular maintenance?*



- Wash at abutments – only known issue



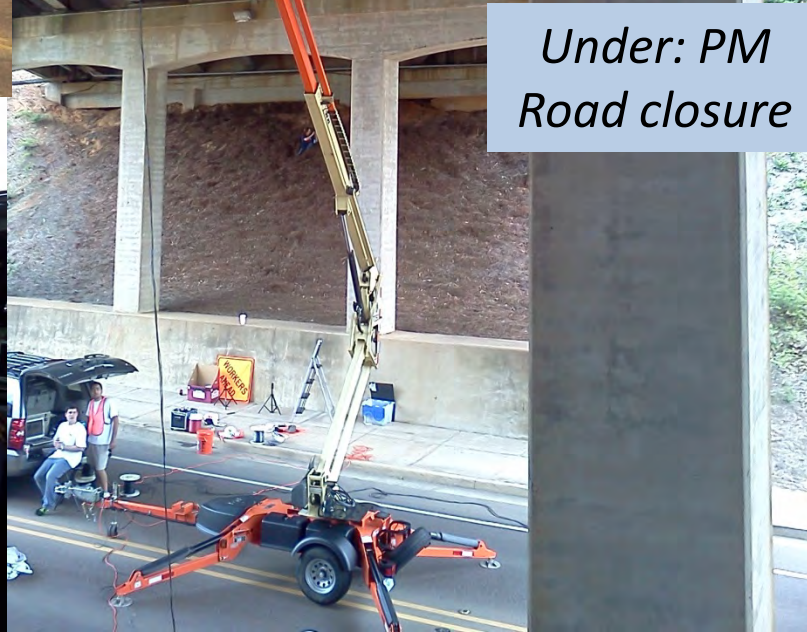
Eastgate Bridge Field Test



*Deck: AM
Single Lane Closure*



*Under: PM
Road closure*

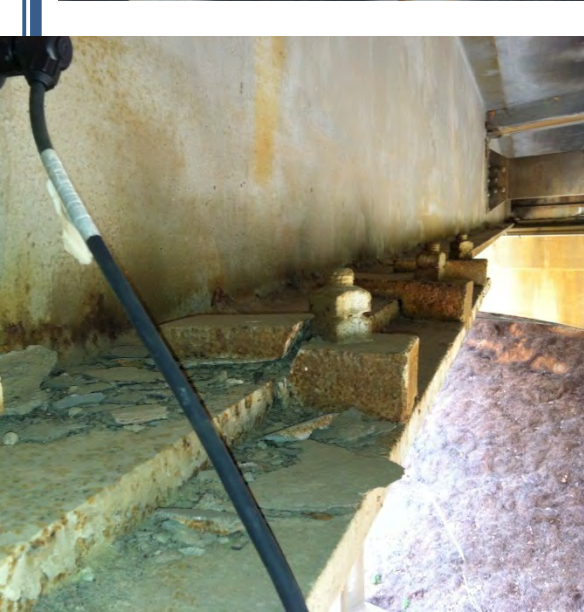


Major Bridge Problem, Field Test

Corrosion: Steam plates/mending plates trapping water from leaking expansion joints → Broken clamps: plates may fall, but bridge globally ok

Ground View: ok, needs paint

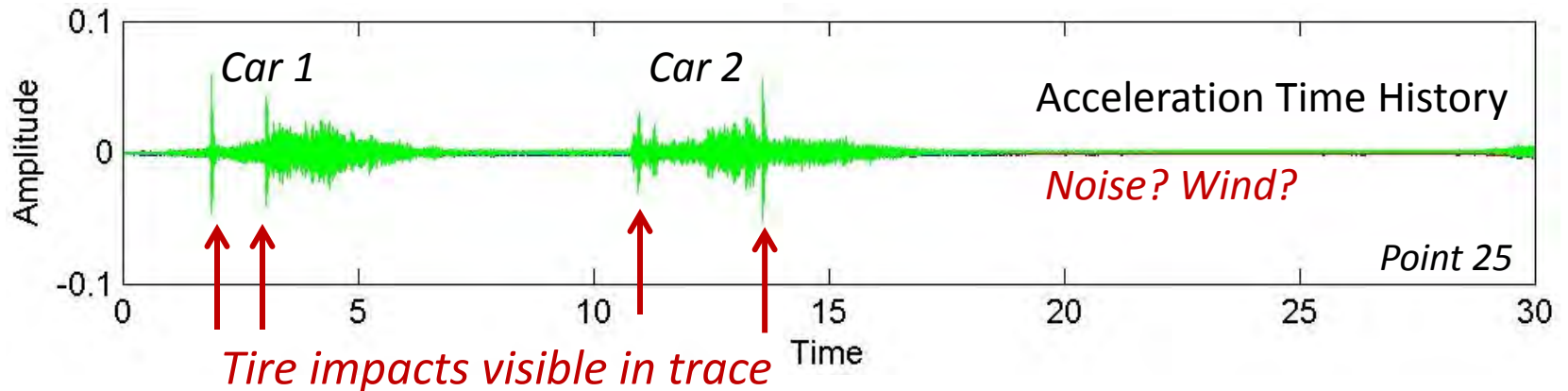
Lift View: corrosion and clamp damage



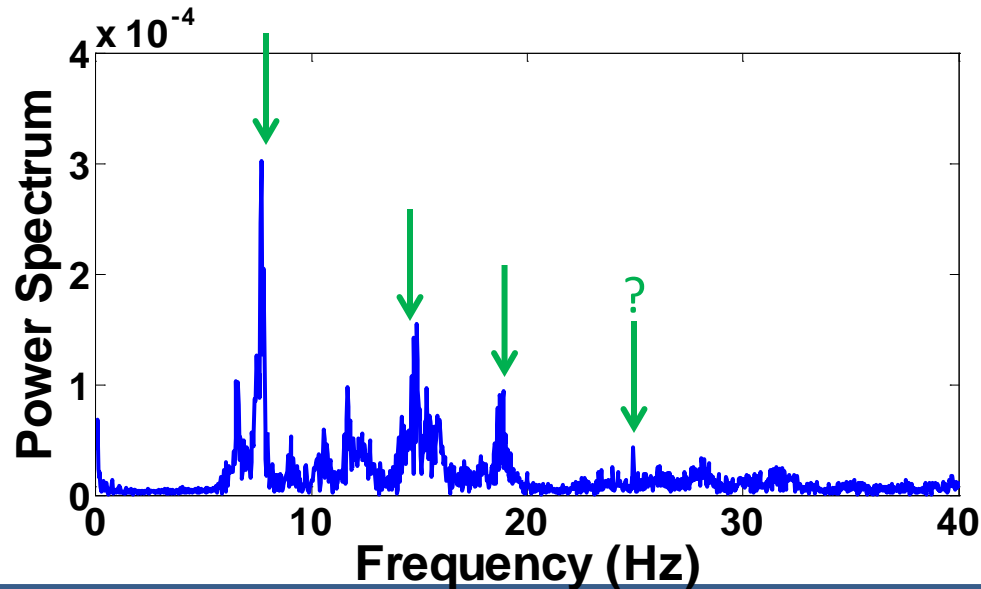
Alerted ALL authorities ASAP

Sensor Results

- Settlement at expansion joints



- Frequency Domain

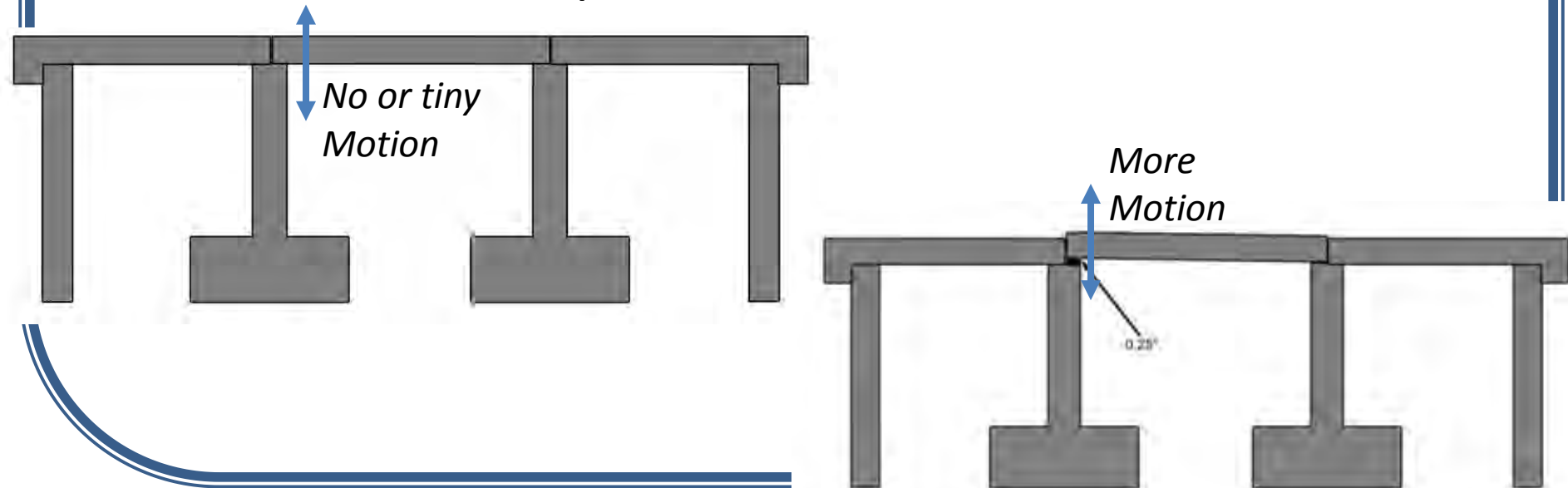


How to sense damage?

1. Acquire time history data from ANY set of sensors
2. Extract frequency content
3. Extract natural frequencies for stiffness decreases

$$\omega_n = \sqrt{\frac{k}{m}}$$

4. Extract mode shapes for location information



Scale Model Bridge

- Design completed by graduate students
- Construction completed by undergraduate students
 - 47 days to build forms and set rebar
 - Concrete poured in April 2013 – “all hands on deck”
 - 37-day cure time then bridge assembled via forklift





If we have time,

<http://youtu.be/SzHHCrNb5m0>

How to quantify damage?

Basic Sensor Properties

Frequency Responses, Natural Frequencies, and Mode Shapes

Baseline case from prior data

Damaged case from current data

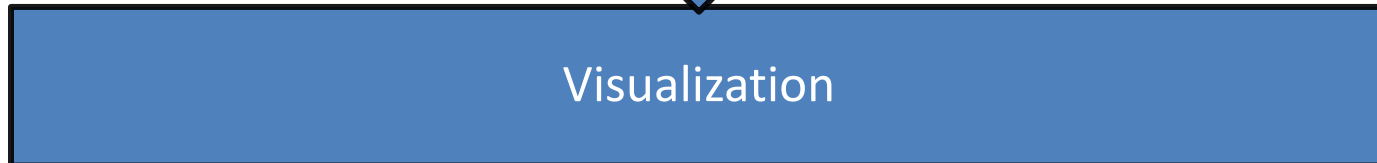
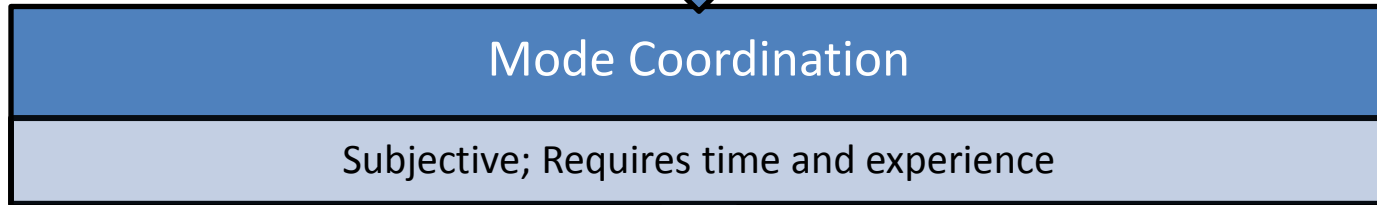
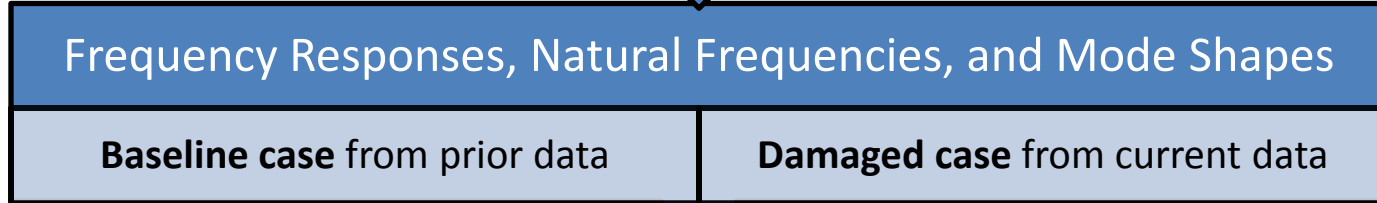
Challenges
to Real-time
Evaluation

Mode Coordination

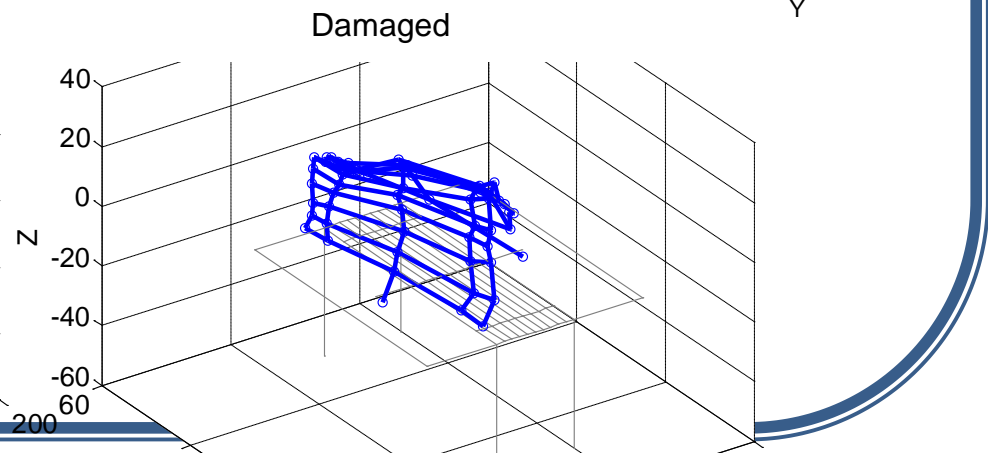
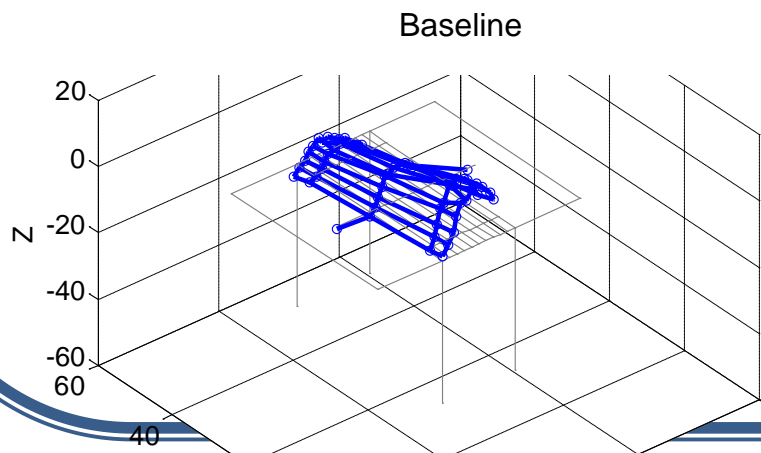
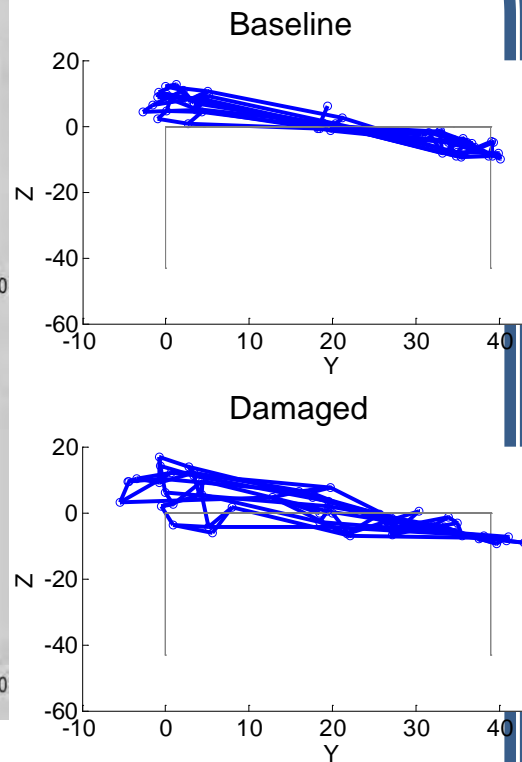
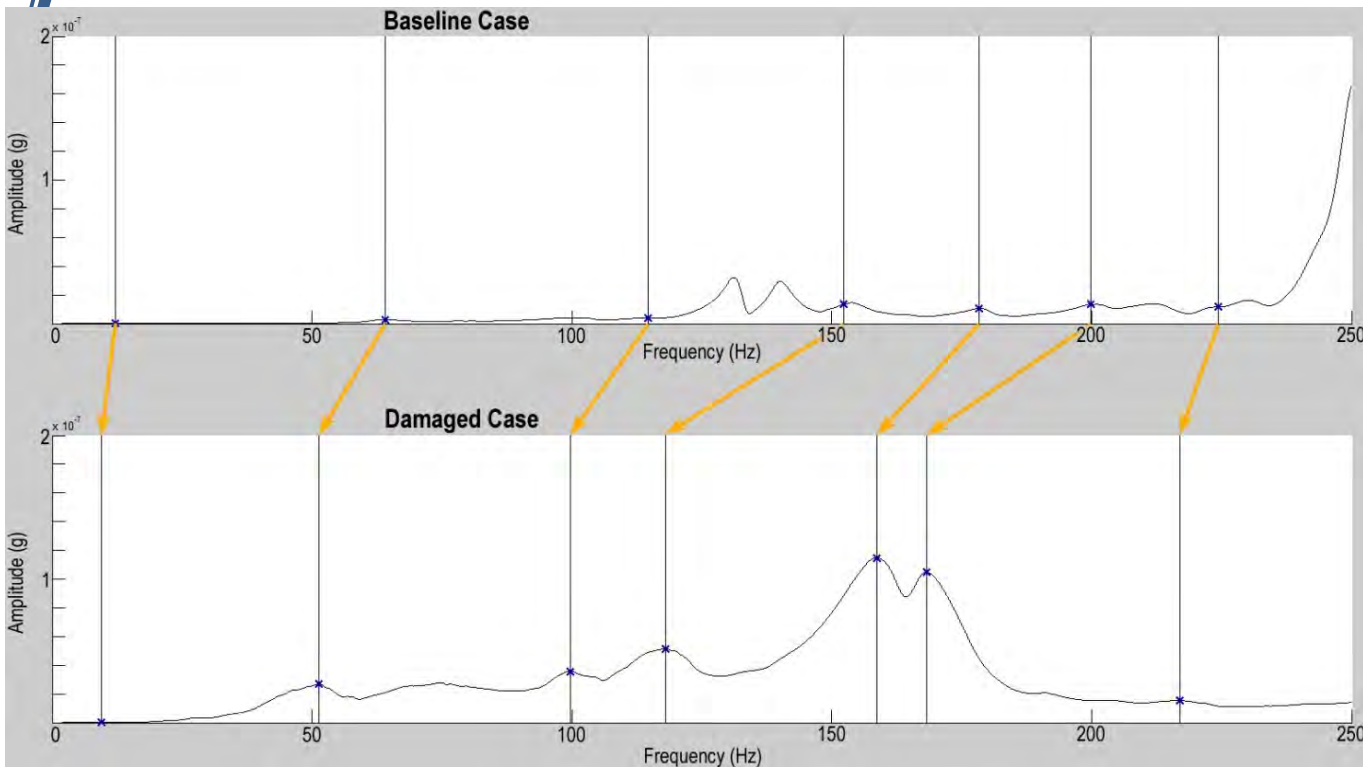
Subjective; Requires time and experience

12 Indicators / Algorithms

Visualization



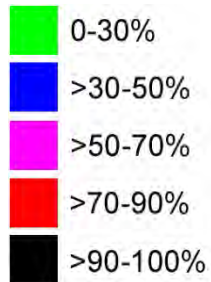
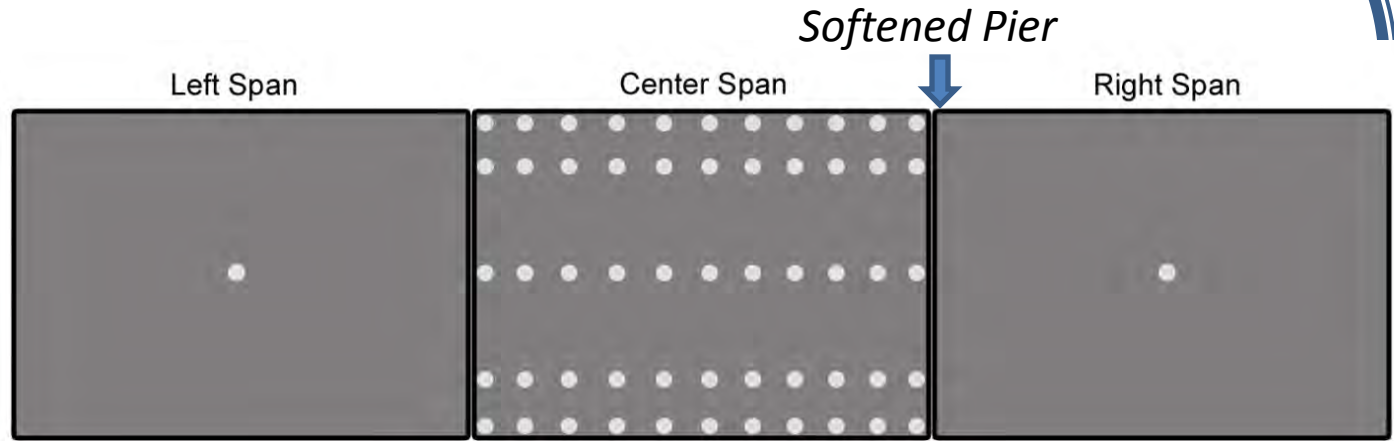
Sample Results



Damage Visualization

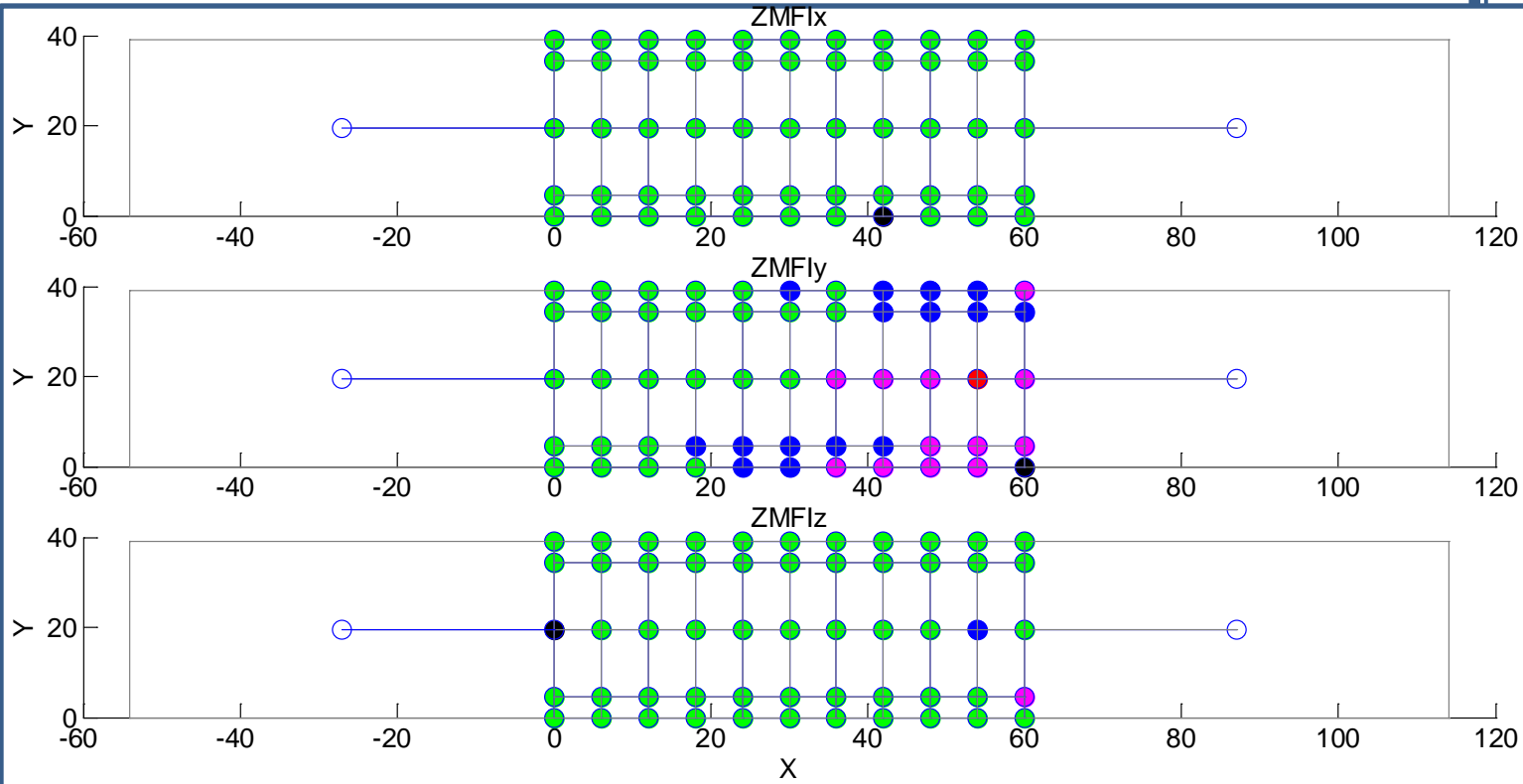
Normalized Modal Flexibility Index

- Each measured direction (3)
- Each sensor location (55)



Arbitrary thresholds at this time

"safe" = ?



Foreseeable Benefit

To detect corrosion and damage before critical.

Potential Product: Improved Inspection Technique(s)

- Remotely judge both severity and location of damage
 - Low modes: “Pier 22 is globally damaging the bridge’s stiffness by 10%.”
 - Higher modes: “The stiffness of Pier 22 is 50% damaged.”
- Remaining life estimation could potentially prevent collapse but, at a minimum, will aid decision-making on the bridge’s maintenance.
- Visualization schemes will best transfer any new technique to field inspectors and/or maintenance workers.

Expected to be...

- more efficient,
- more cost effective, and
- more accurate than visual techniques.

This research requires...

- Civil Engineering
- Mechanical Eng.
- Electrical Eng.
- Computer Sci.

More funding opportunities

Thus far:

Built a railroad, built a scale bridge, and test on-campus bridge

- NCITEC funding (UM Director Uddin)
- National Center for Physical Acoustics (NCPA) collaboration and cooperation





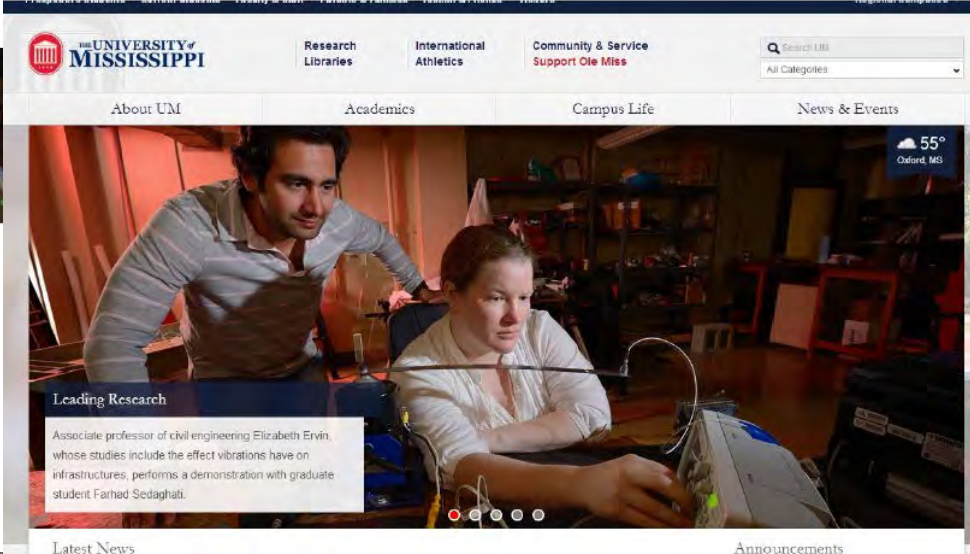
Ervin Sending Out Good Vibrations

Civil engineering professor's shock research shakes things up, breaks them down

October 31, 2013 By [Edwin Smith](#)



YouTube
Film



Application Spotlight: University of Mississippi Uses Modal Shaker and Dynamic Sensors in Bridge Testing Experiments

We are writing today to share with you an interesting application utilizing the versatile **2025E Modal Shaker**. Read the full story below.

Also, please visit our [University Discount Page](#) for more information on Modal Shop products.

The
Modal
Shop,
PCB



Dr. Elizabeth Ervin, Associate Professor in the [Civil Engineering Department](#) at

Announcements

Capability
Handout

YouTube Channel
SHAKENBREAKLAB
(C E 511)

Capability Handout

The Multi-Function Dynamics Laboratory
For the MFDL Website link, see www.engineering.olemiss.edu

The University of Mississippi

Vision
We desire safer infrastructure with enhanced availability in response to abnormal loads as well as aging through structural health evaluation.

Long-Term Goals

- Examine dynamics phenomena to improve R&D in general.
- Improve damage detection from component to system levels.
- Determine appropriate sensing to characterize both ductile and brittle failure during progressive collapse.
- Aid in decision support for first and advanced responders for the four E's: Repair, Rehabilitate, Raze, or Replace?
- Supply additional dynamic experimental studies to open literature.

Interest Areas

- Statistical threshold determination of structural "health" for decision-making.
- Evaluation of damage indicators for real structural systems (following shows).
- Response and damage due to various excitations, including generalized transients, contact/impact, blast, and multi-hazard combinations.
- Fundamental understanding of coupled axial, torsional, and transverse vibrations.
- Vibration reduction, absorption, and control techniques.
- Health and maintenance of nuclear structures, including fuel bundles and steam generator tubes.
- Multi-scale and self-sensing materials that could advance "smart" structures.
- Advanced instrumentation and sensing technology areas, such as shock resistance, piezoelectric energy harvesting, and RFID wireless acquisition.

Location
We are located on the famous Ole Miss circle in Bevard Hall. Come visit us in Rooms 92 and 55.

Core Competencies
The research group is interdisciplinary: civil engineering, mechanical engineering, and computational signal processing. The staff possesses expertise in multiple commercial programs and custom others. The director has 15+ years of expertise in experimental dynamics with shock, vibration, and random excitation, including MIL standards.

Models testing and damage visualization
The University of Mississippi
School of Engineering Experiment

For more information, contact Elizabeth Ervin eke@olemiss.edu