System Observability, Diagnosis, and Prognosis

Project Team:

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NC STATE UNIVERSITY

The DHS Science Conference

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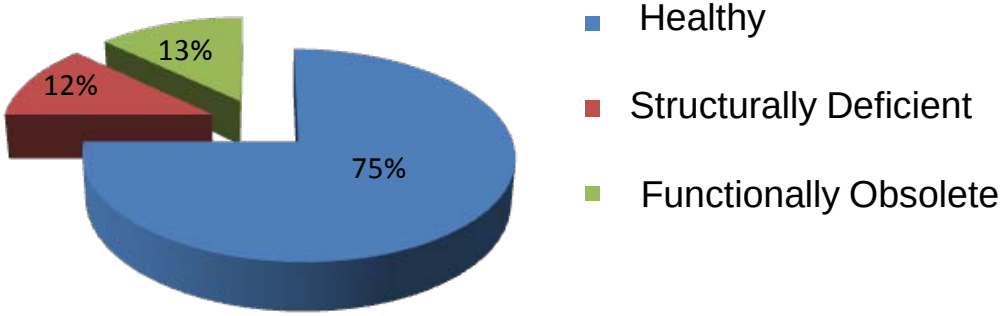
Project Overview

Motivation



The National Bridge Inventory (FHWA 2010)

Types and number of failures (Wardhana et. al., 2003)

Failure causes and events	Number of occurrences	Percentage of total
Hydraulic	266	53
Flood	165	33
Scour	78	16
Collision	59	12
Overload	44	9
Deterioration	43	9

(2)

Project Overview

Objectives

1. Develop a vibration-based damage detection (VBDD) diagnostic framework to:
   - Evaluate the condition of critical coastal bridges prior to an event to enhance resilience.
   - Rapidly assess damage due to scour and at connections following an event to inform decision makers and access by first responders.

2. Develop a prognostics framework.

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Project Relevance to DHS S&T Mission

The outcomes of this project will…

1. enhance community resilience, system robustness and the capacity for recovery,

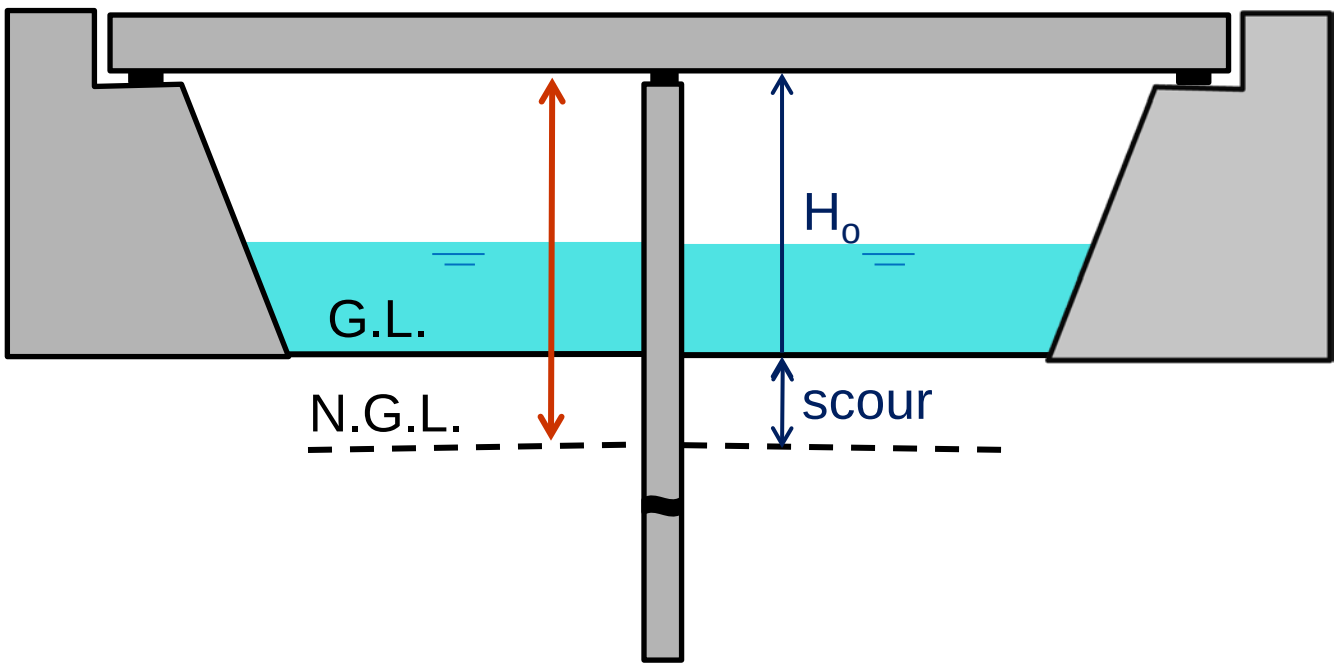
2. ensure resilience to disasters by enhancing preparedness,

3. ensure effective emergency response, and

4. facilitate rapid recovery.

Technical Approach

Basic research concept



Scour → Increase in pile's unsupported height → Decrease in support stiffness → Changes in response of the superstructure

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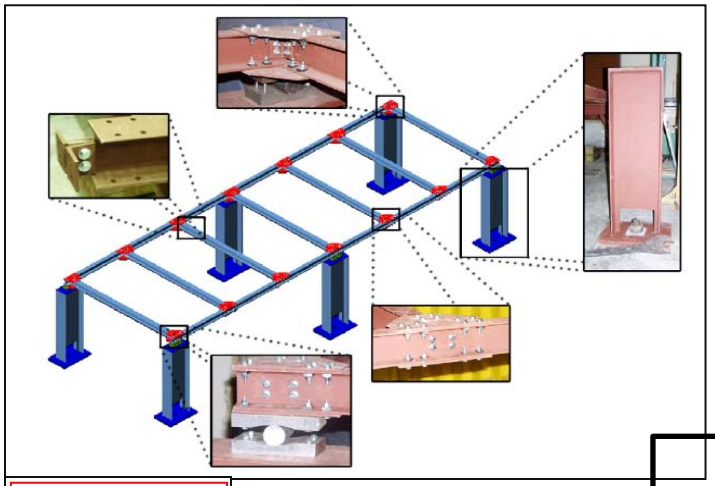
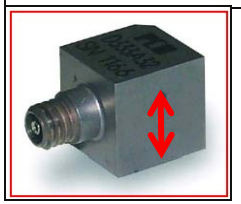
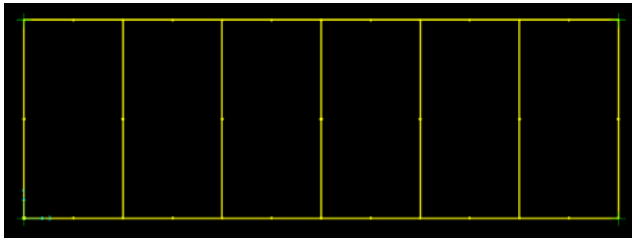
Technical Approach

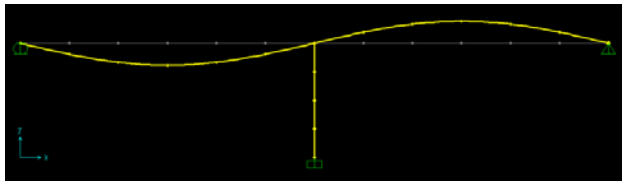




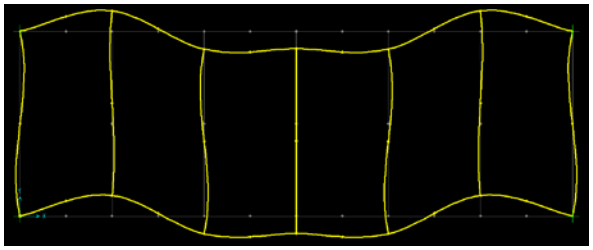
Dynamic Characteristics (Mode Shapes)

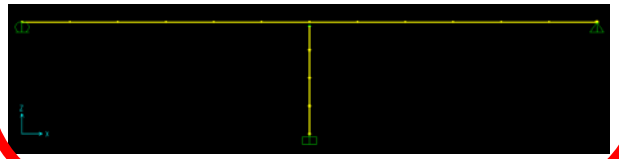
Vertically displaced mode shapes





Horizontally displaced mode shapes

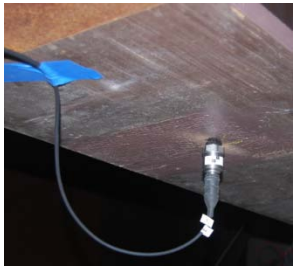


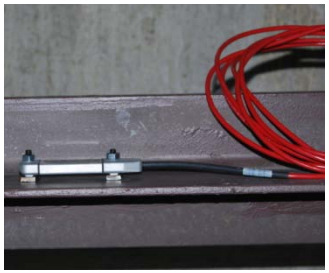


Accomplishments

Field testing of Chicken Road Bridge, NC:

- Quantified effect of daily temperature variation
- Validation of mathematical models

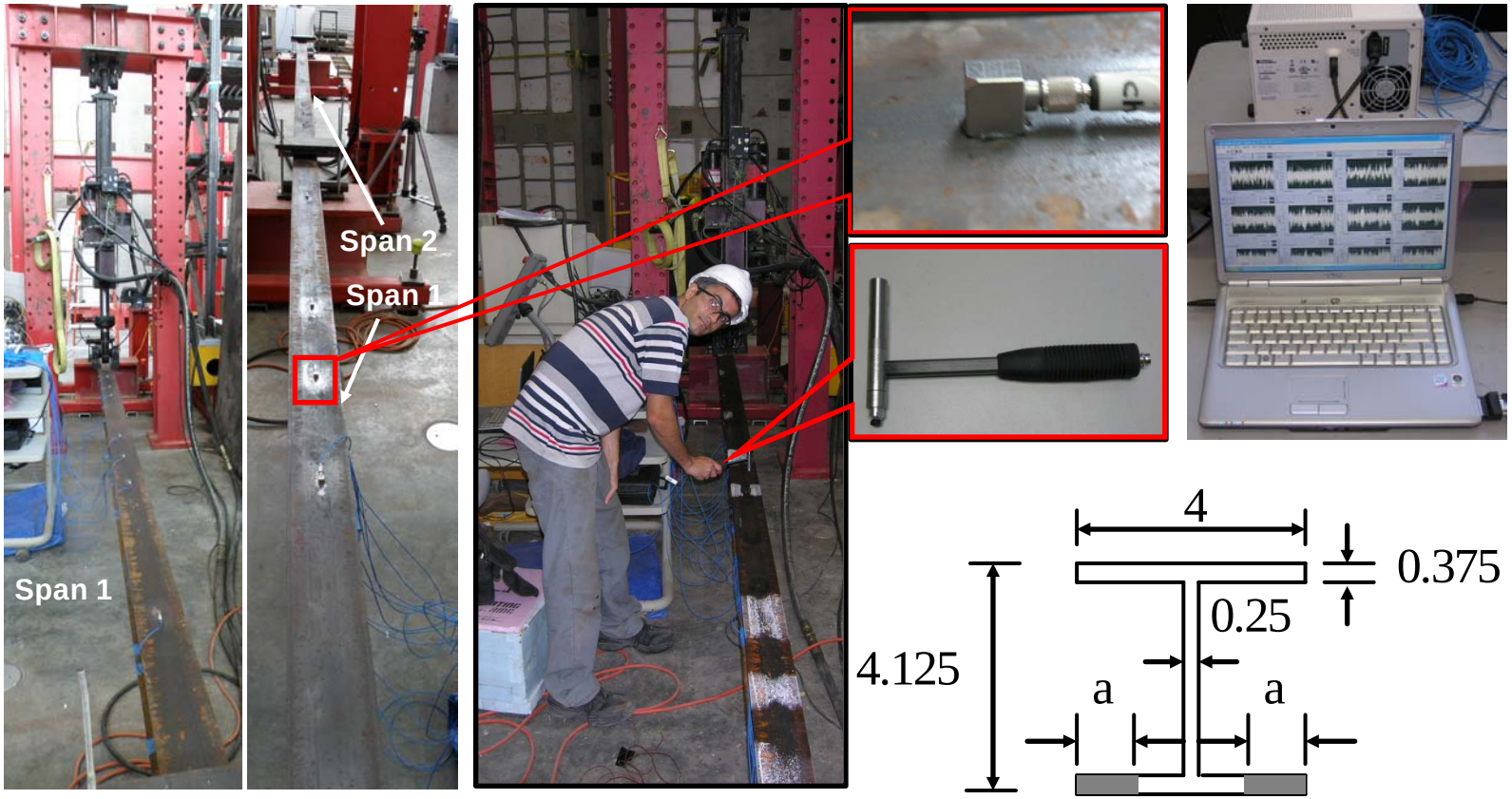




Accomplishments

Lab testing of idealized two-span beam:

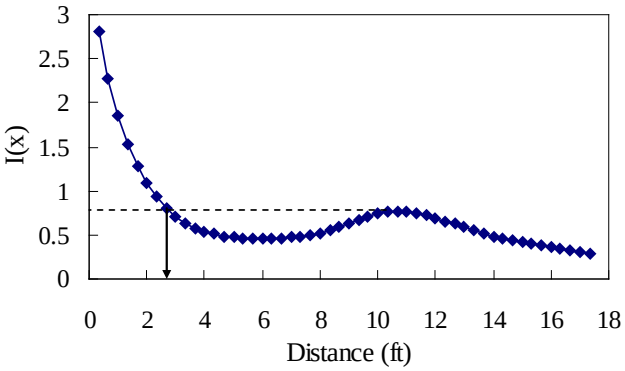
- Test parameters included damage extent and location, loading type, and temperature variation:



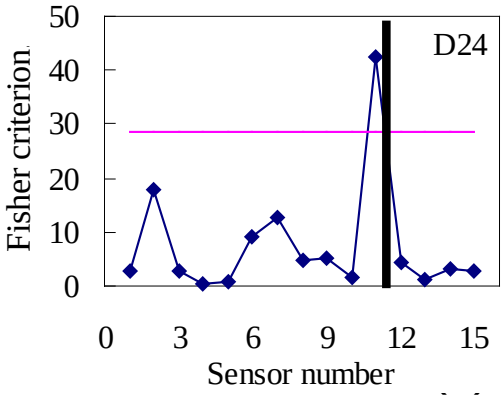
Accomplishments

Developed vibration-based diagnosis framework:

- ***Optimize sensor location:***
  - Concept of mutual information



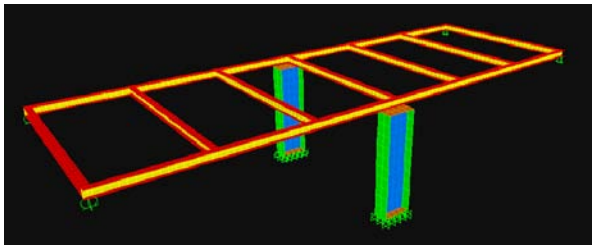
- ***Identify damage existence and location:***
  - Sensitive Damage Features using Mathematical & Statistical tools: Vector autoregressive time series models, Fisher's linear discriminate criterion, Mahalanobis distances.



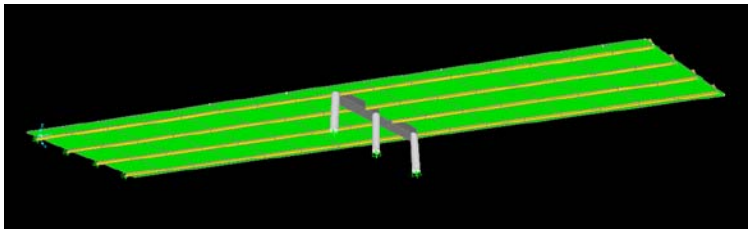
Ongoing Research

Vibration-based damage detection of scour:

- ***Numerical modal analysis***



Idealized two-span grid

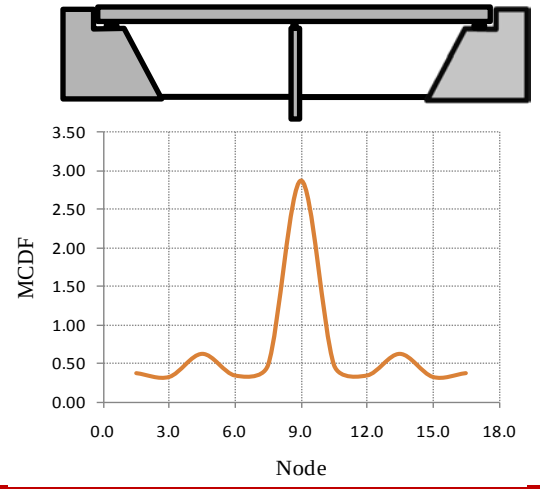


Chicken Road Bridge

- ***Damage features (curvature of mode shapes)***

Proposed *"Modified Curvature Damage Factor"*

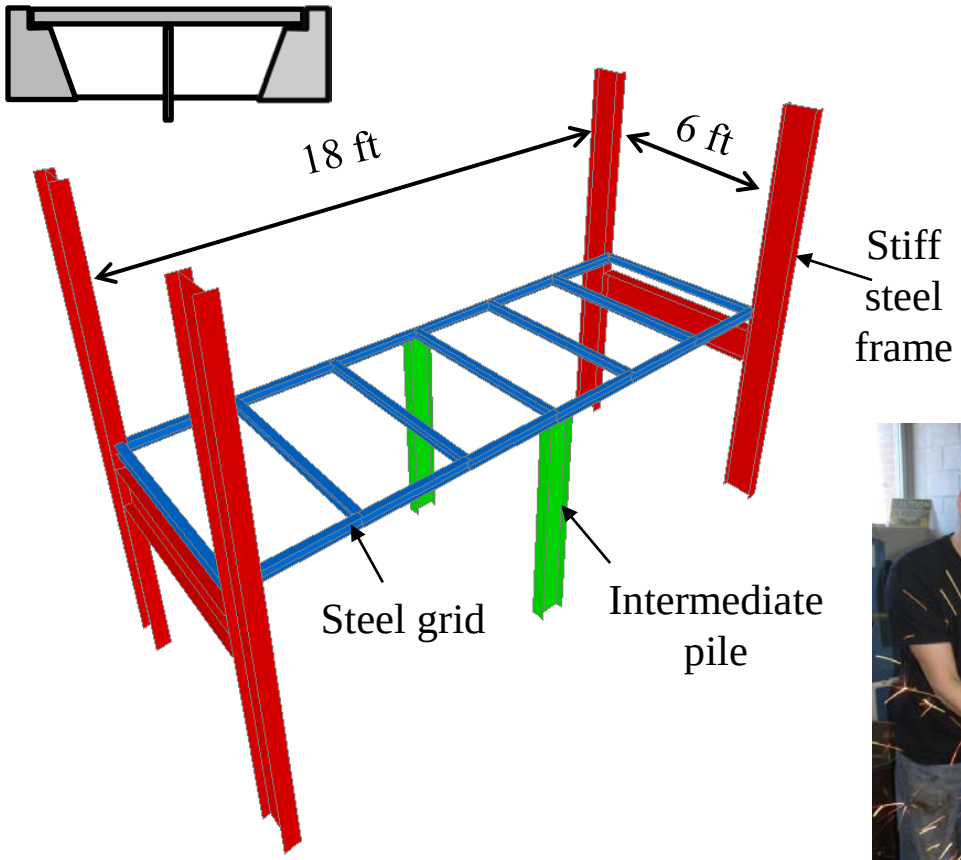
$$MCDF = \frac{1}{N} \cdot \sum_{n=1}^{N} \left| \frac{v''_{0i} - v''_{di}}{v''_{0i}} \right| \quad (10)$$



Ongoing Research

Vibration-based damage detection of scour:

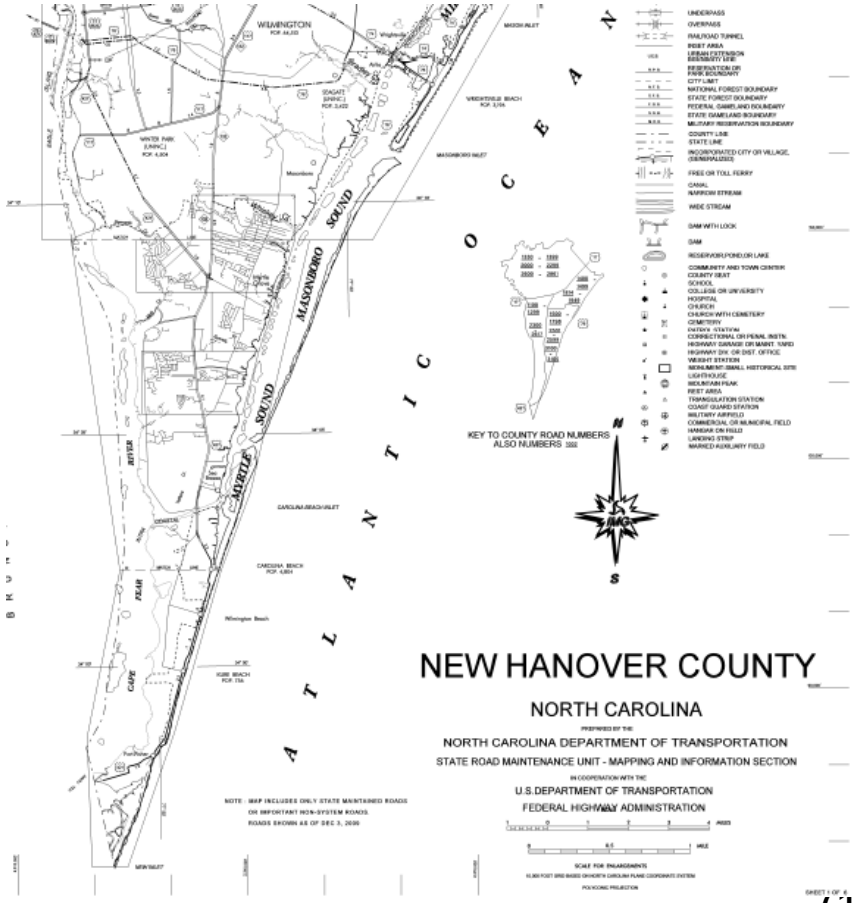
- ***Laboratory evaluation of two-span steel grid***



Ongoing Research

Vibration-based damage detection of scour:

- ***Selection of field investigation site***
  - o Selection of coastal bridge in collaboration with NC DOT Division 3.
  - o Monitoring of Jennette's Pier.



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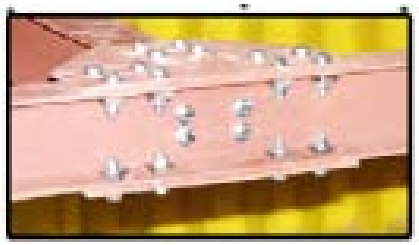
Future Work



1. Develop damage features sensitive to connection damage as well as scour,

2. field monitoring of the selected scour-critical bridge in coastal North Carolina in collaboration with NCDOT Division 3 Bridge Maintenance Engineers,

3. development of prognostic capability to predict the remaining strength/endurance of bridge structures, and

4. development of analysis and visualization tools that will transfer the outcomes of the prognostic assessment into a form suitable for decision making.

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Thank You