Improving Bridge Assessment through the Integration of Conventional Visual Inspection, Non-Destructive Evaluation, and Structural Health Monitoring Data

University of Pittsburg – IRISE (Dr. A.H. Alavi)
Rutgers University – CAIT (Dr. F.L. Moon)
Wiss, Janney, Elstner Associates Inc. – (Dr. S.K. Babanajad)

May 13, 2019
## Bridge Monitoring Technologies

### Complementary Relationship

- **Poor Spatial Resolution + Frequent**
  - Good for large-scale (distributed) & small-medium size (discrete)

- **High Spatial Resolution + Temporal**
  - Good for small-medium size

- **High Spatial Resolution + Frequent**
  - Good for any size
Pennsylvania

- Total of 22800 bridges (~4% of nation)
- Carry I-76, I-79, I-80, and I-81
- 52 yrs avg age & 125 ft avg length
- 25% NBI deck condition rating 5 and below
- 100 large-scale bridges (Max Sp>300 ft)
- 8 suspension bridges
Project Objectives

To establish a framework capable of leveraging emerging SHM, NDE, and advanced Visual Inspection techniques to provide improved performance assessment of bridges

The proposed framework would focus on addressing the principal challenges associated with studying the service life and performance of bridge structures, which are related to:

a) The long-time scales
b) The diverse outputs related to bridge condition
c) Combine (a) and (b) to identify the synergies among bridge degradation, remaining service life, and the results taken from the multimodal sensing technologies
Through a collaboration with the Rutgers’ CAIT and WJE as an industry partner, this research will leverage access to the unique dataset generated by the Bridge Evaluation and Accelerated Structural Testing (BEAST) facility at Rutgers.

**BEAST primary object is to serve bridge practitioners with a nationally shared facility** to validate performance models by measuring stresses and deterioration caused by live, environmental, and maintenance loading in an extremely compressed time frame.
The BEAST – Accelerated Aging of Bridges

Accommodates complete bridge superstructures 50 ft by 28 ft by 5 ft

Two-axle live loading at 10 to 60 kips continuous at 20 mph; 17,000 cycles per day

0 to 104F degrees rapid-cycling temperature fluctuation

Precipitation and salt brine application (1% soluble solution to fully saturated)

Control system and high-speed data acquisition
BEAST History

Sponsored by Federal Highway Administration (FHWA) under Long-Term Infrastructure Program (LTIP)

To be fully commissioned in June-July 2019

Specimen is subjected to rapid-cycling environmental changes and extreme traffic loading to speed up a 15-20 year of normal deterioration in just a 9-12 months period

Will be exposed to over 8 million cycles of live loading (60 kips), 400 freeze-thaw and hot-dry cycles, as well as the application of de-icing agents (6% brine solution) to simulate common winter maintenance practices
BEAST Output

SHM Data
- Deck (embedded/surface strain, temperature, humidity)
- Superstructure (flexural, shear, acceleration, temperature, displacement)
- Substructure (reactions, displacement)

NDE Data
- Impact Echo
- Infrared Thermography
- Ultra Sound Wave
- Ground Penetrating Radar
- Electrical Resistivity
- Half-cell Potential

Visual Inspection
- Surface Crack Mapping
- LiDAR
- HD Images, IR (UAV)
Task 1 - Collection of High-Resolution and High-Temporal Data from the BEAST Specimen

1- Rutgers will provide the data approximately 9-12 months from the start date of specimen commissioning

2- Pitt will help Rutgers in collecting UAV data from the specimen

3- Rutgers and Pitt will customize the collected data for data fusion purposes
1- Further data processing and quality assessment, such as the extraction of delamination condition indexes from IE maps (Pitt and WJE)

2- Pitt and WJE will collaborate to determine certain performance indexes from the data to fuse within a multi-modal integration framework
Task 3 - Advanced Statistical Data Analytics

Advanced statistical data analysis techniques (inclusive of Machine Learning (ML) and Artificial Intelligence (AI)) for data reduction, data fusion, and exploratory analysis.

Multiple model structural identification methods

A deep convolution neural network
Task 4 - Development of Recommendations

1- Assess different case scenarios defined based on the variation of spatial resolution, temporal resolution, type of data, and their effectiveness in the determination of bridge condition

2- Determine the effectiveness of each sensing technology (or a group of techniques in conjunction of each other)

3- Conduct a preliminary cost-benefit analysis on each/combined sensing technology(s)
Deliverables

1- Final Report

2- Technical Articles

3- Technical Events (TRB, NEBPP)
## Schedule

<table>
<thead>
<tr>
<th>Months</th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1</td>
<td>Q2</td>
</tr>
<tr>
<td>Task 1: Collection of Data from the BEAST Specimen</td>
<td>☢️ ☢️ ☢️</td>
<td></td>
</tr>
<tr>
<td>Task 2: Processing of Collected Data</td>
<td></td>
<td>☢️ ☢️ ☢️</td>
</tr>
<tr>
<td>Task 3: Advanced Statistical Data Analytics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 4: Development of Recommendations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Draft Final Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Report</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Thank you

Amir H. Alavi, PhD
Assistant Professor
Department of Civil and Environmental Engineering
University of Pittsburgh
E-mail: alavi@pitt.edu