Bridge Instrumentation for Long Term Structural Health Monitoring

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Presentation Outline

• Background
• Instrumentation
• Load Test
• Modeling
• Model Calibration
• Conclusions
National Science Foundation Partnership for Innovations

• Stimulate the *transformation* of knowledge created by the research and education enterprise into *innovations* that create new wealth; build strong local, regional and national economies, and improve the national well-being.

• Broaden the participation of all types of *academic institutions* and all citizens in activities to meet the diverse *workforce* needs of the national innovation enterprise.

• Catalyze or enhance enabling infrastructure that is necessary to foster and *sustain innovation* in the long-term.
New Bridge Design Paradigm

• Go beyond opening day design
  – Creation of baseline model
  – Integrate baseline modeling and model updating through bridge service life

• Modify reactive mode of bridge management
  – Develop useful and cost-effective bridge instrumentation plan
  – Deploy practical nondestructive tests
  – Have continuous feedback from bridge about current structural health
Vernon Avenue over the Ware River Bridge
Barre, MA

Image Courtesy of Google Maps
Vernon Avenue over the Ware River Bridge
Barre, MA
Instrumentation Plan
Instrumentation Plan (Top View)
Instrumentation Plan (Side View)
## Instrumentation Summary

<table>
<thead>
<tr>
<th>Summary</th>
<th>Count</th>
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</thead>
<tbody>
<tr>
<td>100 Strain Gauges</td>
<td></td>
</tr>
<tr>
<td>36 Temperature Sensors</td>
<td></td>
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<tr>
<td>36 Concrete Temperature</td>
<td></td>
</tr>
<tr>
<td>16 Accelerometers</td>
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<tr>
<td>12 Tiltmeters</td>
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<td>3 SWP</td>
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<td>4 Bi-Axial Tilt</td>
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Instrumentation by Geocomp
Concrete Pour
Truck Loading
Truck Tracking Using ATMS

(Automated Motorized Total Station)
Bridge Modeling

Model Using SAP2000 Bridge Modeler (BrIM)

Model Using SAP2000 Solid and Shell Elements
Modeling Requirements

• Detailed finite element model that captures bridge performance
  – Exact geometry
  – Including bridge components such as diaphragms, safety cubs, and concrete haunches
Crawl Speed Load Test

Path X1, Girder 1, Station 6, Bottom Flange, SG-6

Path X1, Girder 1, Station 8, Bottom Flange, SG-8
Crawl Speed Load Test

Path X1, Girder 1, Station 6, Bottom Flange, SG-6

- Measured
- Initial Model
- Updated Concrete
- Safety Curbs
- $\Gamma=91\%, \Gamma^*_{100\%}$

Micro Strain (µε)

Time (seconds)

10:57:00
10:58:00
Conclusions

• Detailed 3D FEM of typical highway bridges is feasible to a high degree of accuracy
• Truck load testing performed on a newly constructed bridge can provide highly reliable strain data for calibrating baseline FEM’s.
• Calibrated FEM and load test strain data matched closely
• A calibrated FEM can be used as an effective tool for bridge management
Thank You for Listening

Acknowledgements

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“Whatever Happened to Long Term Bridge Design?”
Program Director: Dr. Sara Nerlove

MassDOT – Bridge Construction

Town of Barre, MA – Bridge Management and Owner

E. T. & L. Corp. – Bridge Contractor

High Steel Structures, Inc. – Steel Fabricator

Atlantic Bridge and Engineering, Inc. – Steel Erector

Fay, Spofford & Thorndike, Inc. – Bridge Design

Geocomp Corporation – Instrumentation

Bridge Diagnostics, Inc. – Bridge Testing
SUPPLEMENTARY SLIDES
Objective Function for Manual Model Updating

\[ J = \frac{1}{n} \sum_{i=1}^{n} \sum_{j=1}^{s} \left( \frac{e_{ij}^a - e_{ij}^m}{\sigma_{ij}^m} \right)^2 \]

Scalar Objective Function for Crawl Speed Test

![Graph showing objective scalar function for different scenarios: Initial Model, Updated Concrete, Safety Curb, 91%, 100%](image-url)