"Whatever Happened to Long-Term Bridge Design?"

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Brief Project Overview:

Advances in structural analysis, instrumentation, data management, and reporting make it feasible to consider alternate approaches for bridge design. A new procedure can incorporate development of a "baseline" bridge model that can be used for structural health monitoring (SHM) of the bridge over its lifetime. Regular and effective use of SHM for bridges can provide more objective data on bridge conditions over time and lead to improved maintenance for more efficient use of limited resources. This approach has great promise at a time of aging infrastructure and limited funds for maintenance and repair.

Program Activities:

1. Access was provided by the Town of Barre for use of Vernon Avenue over the Ware River Bridge as the target bridge for SHM during construction phase and throughout service life, Fig.1.
2. Two initial structural models were created using SAP2000®. One model used solid and shell elements (fine model), Fig 2., and the other used the Bridge Modeler (coarse model).
3. These models were used to design an instrumentation plan of more than 200 sensors including strain gauges, tiltmeters, accelerometers and temperature gauges, Fig. 3.
4. This instrumentation plan was deployed starting at the steel fabrication yard prior to shipment.
5. Data was collected throughout the construction process, including the concrete deck pour.
6. A load test was performed on 3 September 2009.
7. Since the load test, data collection and quality analysis was performed in anticipation of model calibration and design verification.
8. Initial model calibration shows an excellent match, Fig. 4.

Top Contributions/Outcomes :

1. Performing two major data acquisition milestones: one during bridge deck concrete pour and the second one during the load test after completion of the bridge.
2. Creation of two finite element models of the bridge for comparison with nondestructive test data: one coarse model and one fine model.
3. Use of the nondestructive load test data for finite element model updating for bridge design verification and load rating.

Top Challenges:

1. Securing access to a target bridge in an ever-changing construction market and communications with the local, state, and government agencies responsible for the construction of the bridge.
2. Instrumentation and data acquisition during the construction side by side of steel erectors and construction workers during a rapid construction schedule.
3. Use of the nondestructive data to as a platform for bridge design verification and as a bridge management tool.

Partners:

1. Fay, Spofford & Thorndike, Inc. – Bridge Design
2. Massachusetts Department of Transportation – Bridge Construction
3. Town of Barre, MA – Bridge Management and Owner
4. E. T. & L. Corp. – Bridge Contractor
5. High Steel Structures, Inc. – Steel Fabricator
6. Atlantic Bridge and Engineering, Inc. – Steel Erector
7. Geocomp Corporation – Instrumentation
8. Bridge Diagnostics, Inc. – Bridge Testing

Fig.1 Vernon Avenue Bridge over Ware River – instrumented bridge

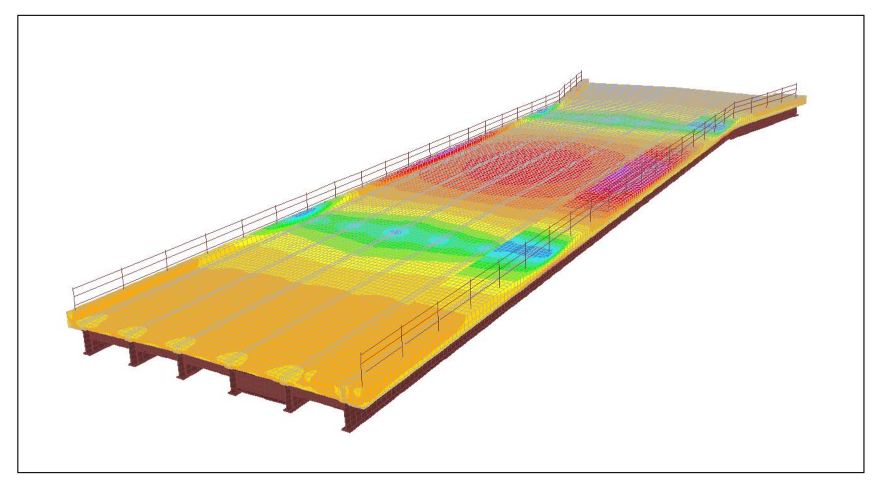

Fig. 2 Finite element model (FEM) created using SAP2000®

Fig. 3 Data acquisition units under Vernon Avenue Bridge

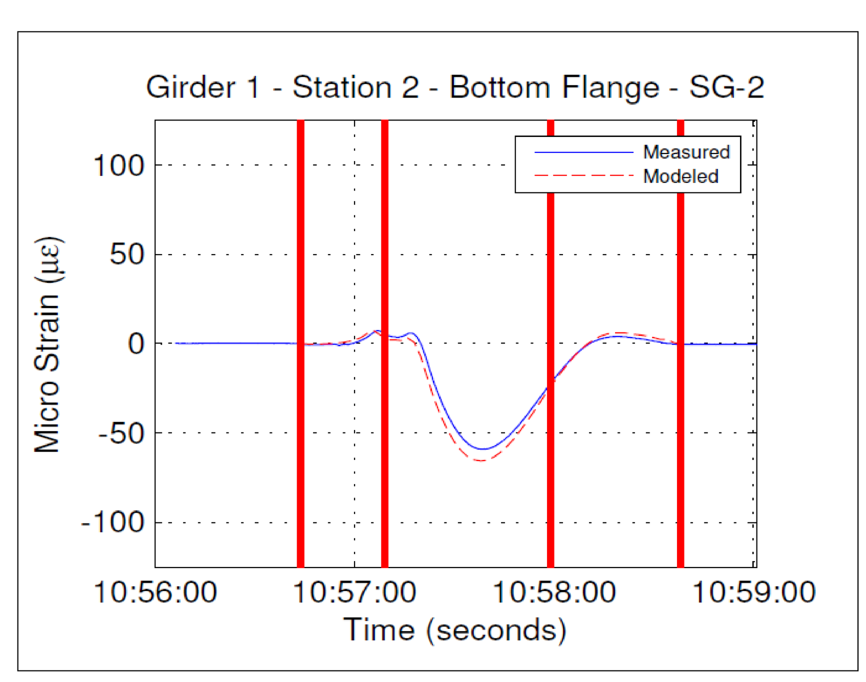

Fig. 4 Example of FEM data compared with measured data

Fig. 5 Tobin Memorial Bridge

Key Attributes of our Innovation Ecosystem:

Questioning & Curiosity:

- Difference between bridge system behavior and element by element behavior, which is typically used in design
- Difference between response and design expectations
- Can instrumentation enhance infrastructure maintenance through sustaining innovation

Risk Taking:

- Construction participants partnered with research team to ensure that overall bridge project costs and schedule were not adversely impacted
- Data acquisition during construction might result in additional questions about procedures
- Parties involved have a responsibility to public safety
- The paradigm of more rigorously accounting for long term issues in the initial design may result in new liabilities and risks that need to be explored

Openness:

- Construction partners cooperation and interest was paramount to success of the project
- University partners shared data and ideas openly
- Geocomp gave training on instrumentation and established feedback loop
- BDI provided training on bridge nondestructive testing

Collaboration Across Fields:

- Feedback loop between technical side of instrumentation and practical side of data acquisition
- Participants of academic institutions working together with the workforce of bridge construction
- Research on bridge design, instrumentation, and testing

Placing Partners in "New Environments" & "Playgrounds":

- Changing the paradigm of bridge design and management: more rigorous consideration of long term issues; considering analytical basis of design throughout life of bridge; system modeling as opposed to element modeling
- Taking advantage of technology to look at an old problem in a new way
- This project will also provide insight to researchers and academics on how structural finite element model updated can be done on a structural model of a full-scale in-service bridge with several data sets collected from various types of measurements

Leading / Inspiring of Surprising or Unexpected Results:

- Instrumentation can be performed during construction while satisfying overall schedule requirements
- Feedback loop between Geocomp and researchers to advance field of bridge instrumentation
- As an offshoot of the NSF-PFI project, the research team was fortunate to work on another project, Tobin Memorial Bridge analysis and instrumentation, Fig. 5