John DeVitis, PhD

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Summary

John conducts multidisciplinary research as a Research Associate at the Rutgers Center for Advanced Infrastructure Technology (CAIT). As a researcher, his goal is to provide meaningful contributions to the civil space that solve real problems. This work began with the design, development, and validation of a rapid, self-contained modal impact system for testing highway bridges at a reduced effort and cost than current bridge testing approaches. Through this effort, the Targeted Hits for Modal Parameter Estimation and Rating (THMPER) system has been utilized for structural testing of multiple highway bridges including eleven bridges from the FHWA Long Term Bridge Performance Program's (LTBP) Mid-Atlantic cluster and seven bridges from the North-West cluster. The THMPER system has also recently been awarded the 2017 Charles Pankow Award for Innovation which is a great honor. John's current research has invovled using innovative experimental methods to recover information regarding unknown bridge foundations. This is the aim of the recently awarded EAGER NSF grant titled "Informaing Infrastructure Decisions through Large-Amplitude Forced Vibration Testing" for which he is a Co-PI.

Skills

Design: Design-driven innovation, small and large scale, concept of operations, system requirements, system design, hardware and software design, prototyping, component and system validation

Data Science: Data processing and visualization, digital signal processing, graphical user interfaces, data interpretation, QA/QC, Matlab/Octave, Python, NI LabVIEW

Structural Health Monitoring: Design of experiments, logistics, temperature testing, diagnostic truck load testing, ambient vibration monitoring and operational modal analysis, force vibration testing

Bridge Practice: Structural-Identification, field testing logistics, FHWA LTBP, LRFD

Modal Analysis: Operational modal analysis (signature structures), experimental modal analysis (highway bridges), multi-reference-impact-testing, transient and steady-state testing, single-degree-of-freedom and multi-degree-of-freedom modal parameter estimation, pre- and post-processing, result archival

Real-Time Systems: NI LabVIEW, CompactRIO, data acquisition, hardware and software, framework and architecture, concurrent programming, actor oriented programming

• *See attached '**Selected Works**' section for more detail* •

Appointments

Center for Advanced Infrastructure and Transportation, Rutgers University — New Bruswick, NJ

Research Associate — *Feb '16 – present*

Managing research, leading field testing activities, directing graduate students, outreaching with potential clients and agency representatives, presenting to infrastructure stakeholders, investigating funding opportunities and writing proposals, collaborating with external consultants and industry partners, submitting schedules, and reviewing academic journals.

DI3 Lab, Drexel University — Philadelphia, PA

Research Fellow — *Aug '10 – Jan '16*

Taught undergraduate classes in structural analysis and modeling, conducted applied structural engineering research, wrote status reports. Planned and executed field tests and infrastructure evaluation.

Intelligent Infrastructure Systems — Philadelphia, PA

Graduate Engineer — *Mar '12 – present*

Aid in the design and implementation of data acquisition and sensing systems, field installation, sensor and acquisition debugging, interpretation, visualization.

Education

Drexel University — Philadelphia, PA

PhD in Civil Engineering — *Jul '10 – Dec '15*

Dissertation Title: *Design, Development and Validation of a Rapid Modal Testing System for the Efficient Structural Identification of Highway Bridges*

BS in Civil Engineering — *Sept '07 – Jun '10*

Research Proposals Awarded

- *'EAGER: Informing Infrastructure Decisions through Large-Amplitude Forced Vibration Testing,'* N. Gucunski (PI), J. DeVitis (Co-PI), F. Moon (Co-PI). NSF Award Number CMMI-1650170, 8/1/2016-7/31/2017, Sponsor Funding: $235,318

- *'Refined Load Rating through Rapid Modal Testing,'* F. Moon (PI) and J. DeVitis (Co-PI). National University Transportation Center Consortium led by CAIT, 7/1/2017-9/30/2017, Sponsor Funding: $38,039

Publications

- Mao, Q., Mazzotti, M., DeVitis, J., Braley, J., Young, C., Sjoblom, K., Aktan, A. E., Moon, F., Bartoli, I. (Submitted 2017) *'Characterization and Evaluation of Bridge Substructure and Foundation using Structural Identification,'* Structural Control and Health Monitoring

- Mao, Q., DeVitis, J., Mazzotti, M., Braley, J., Bartoli, I., Sjoblom, K., Moon, F., Aktan, A. E. (2016). *'Dynamic Evaluation of a Bridge Substructure with Experimental Modal Analysis,'* Geotechnical and Structural Engineering Congress 2016; doi: 10.1061/9780784479742.161

- Hu, X., Trias, A., DeVitis, J., Moon, F., Roda, A., Fan, Z., Gong, J. (2016). *'LiDAR Data Efficiency for Geometry Centered Bridge Condition Investigation,'* International Workshop on Computing in Civil Engineering

- Furkan, M., Mao., Q., Mazzotti, M., DeVitis, J., Sumitro, P., Faridazar, F., Aktan, A. E., Moon, F., Bartoli, I. (2016) *'An investigation on wireless sensors for asset management and health monitoring of civil structures,'* Proc. SPIE 9803, Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems 2016, 98033E (April, 20,2016); doi: 10.1117/12.2218908

- Mao, Q., J. DeVitis, M. Mazzotti, I. Bartoli, F.L. Moon, K. Sjoblom, and A.E. Aktan (2015) *'Boundary condition identification for a grid model by experimental and numerical dynamic analysis,'* SPIE Smart Structures and Materials + Nondestructive Evaluation and Health Monitoring, International Society for Optics and Photonics, San Diego, CA

- DeVitis, J., D. Masceri, J. Braley, N. Romano, A.E. Aktan, and F.L. Moon (2014) *'Overview and Preliminary Validation of a Self-Contained Rapid Modal Testing System for Highway Bridges,'* 6th World Conference of International Association for Structural Control and Monitoring, Barcelona, Spain

- DeVitis, J., D. Masceri, J. Braley, N. Romano, A.E. Aktan, and F.L. Moon (2014) *'Preliminary Validation of a Rapid Modal Testing Prototype for Population Based Condition Assessment of Highway Bridges,'* Annual Conference of the American Society for Nondestructive Testing, Washington, D.C.

- DeVitis, J., D. Masceri, A.E. Aktan, and F.L. Moon (2013) *'Rapid structural identification methods for highway bridges: towards a greater understanding of large populations,'* 11th International Conference on Structural Safety & Reliability, June, Columbia University, New York, NY

- DeVitis, J. and F.L. Moon (2012) *'Realization of a Global Structural Assessment System,'* NDE/NDT for Highways and Bridges Conference, American Society for Non-Destructive Testing (ASNT), New York, NY

- Zhou, Y., J. Prader, J. DeVitis, D. Masceri, A. Deal, F.L. Moon, and A.E. Aktan (2011) *'Rapid Bridge Modal Analysis for Global Structural Assessment,'* Experimental Vibration Analysis for Civil Engineering Structures (EVACES), Verenna, Italy

- Zhou, Y., J. Prader, J. DeVitis, A. Deal, J. Zhang, F.L. Moon, and A.E. Aktan (2011) *'Rapid Impact Testing for Quantitative Assessment of Large Populations of Bridges,'* SPIE, Nondestructive Characterization for Composite Materials, Aerospace Engineering, Civil Infrastructure, and Homeland, San Diego, CA.

Awards, Patents, and Certifications

- **Patent Pending *(2015-present)*** *Self-Contained Rapid Modal Testing System for Highway Bridges* Publications US20170160165A1, EP3158307A1, WO2015195728A1

- **Charles Pankow Award for Innovation *(2017)*** American Society of Civil Engineers

- **Certified LabVIEW Associate Developer *(2013)*** LabVIEW Core 1, Core 2, FPGA

- ***Misc:*** Vertical Lift Training (2016), Confined Space Training (2014), Fall Protection Training (2014), Secure Worker Access Consortium Membership (2013), Lead Awareness Training (2012)

Selected Work *John DeVitis, PhD*

The following expands on the Skills section of my resume. It's a portfolio of sorts. Using a selection of work from past and current projects, I hope to better describe my unique skillset and experience.

- John

Contents

1 Design

My dissertation research focused on designing, developing, and validating a modal testing system for highway bridges. In addition to exposing me to multiple engineering disciplines outside of the civil field, it revolved around design - both at a high-level system design and low-level, finer-grained, hardware and software design. The research, which was funded by the National Institute for Standards and Technology - Technology Innovation Program (NIST-TIP), gave me a unique experience to personally see a product from conception through implementation to validation, both at a system and a component level. Below is a brief overview of this work.

1.1 System Design

The Targeted Hits for Modal Parameter Estimation and Rating (THMPER) system was developed to mitigate many of the constraints associated with conventional highway bridge testing by performing modal impact testing in an accelerated manner. The system is comprised of a self-contained modal testing trailer, a mobile work station, and streamlined data processing software to extract modal parameters (natural frequencies and global mode shapes) of highway bridges in an efficient, rapid manner. The modal testing trailer is comprised of a Falling Weight Deflectometer (FWD) that was significantly reconfigured to (1) provide a single, large (30kip) broadband impact source, and (2) collect the resulting free-decay response of the bridge's surface both locally (at the impact location) and globally (via stationary sensors installed along available sidewalks/shoulders out of the way of traffic).

Figure 1: THMPER System

High-level system design was approached using the "V" model for systems engineering (National ITS Architecture Team, 2007). This forced the explicit documentation of key design elements such as *(1) Conceptual Development, (2) System Requirements, (3) Strategic Development, (4) Hardware and Software Design, and (4) System and Component Validation.*

1.2 Strategy

Partial traffic control is used to install a single line of stationary sensors along the exterior sides of the bridge. These sensors remain throughout the entirety of the test and are ideally installed along an available sidewalk or shoulder. Depending on the length and number of spans of the bridge, this typically requires fifteen to thirty minutes of traffic control prior to testing to fully install and less to break down post-test. Measurements within the roadway are performed by roving the modal impact trailer to selected locations along the bridge deck and performing several local Single Input Multiple Output (SIMO) impact tests. Each record is approximately ten seconds in duration and typically only three to five are required at each impact location (for averaging purposes). As a result, the total time spent in the actual road-way is relatively short (on the order of 3-5 minutes per impact location) and may be acquired during brief traffic slow-downs or temporary single lane closures.

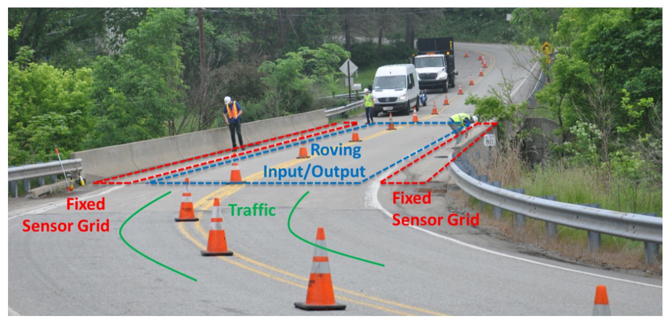

Figure 2: THMPER Measurement Strategy

1.3 Hardware

A schematic of the prototype THMPER trailer is presented in Figure 3. Utilizing an NI cRIO micro-controller and pneumatic actuators, a local sensor array presses spring loaded accelerometer housings onto the bridge deck. A hydraulic lift system then raises an impact carriage with configurable mass and stiffness. The impact carriage is dropped, impacts the bridge deck and rebounds upwards. A sensing/control system utilizing hall sensors detects the impact and triggers fast acting pneumatic actuators which extend upwards to catch the mass, preventing subsequent rebounds. The impact causes a 25,000 – 30,000lb unit impulse force with frequency content between 50 – 65 Hz. During testing, an independent data acquisition system utilizing GPS synchronized records acquires several stationary accelerometers to use as spatial and modal references for post processing analysis. Several impact sequences are performed in a rapid succession at each location for averaging during FRF development and, once completed, the mobile sensing array is raised and the trailer is towed to a new location on the bridge deck.

The primary components of the test trailer consist of:

- A single, repeatable impact device with focused frequency band

- A robust, mobile, rapidly deployable sensing array
- An integrated data acquisition and machine control system
- A wireless, GPS synchronized remote sensing and data acquisition system

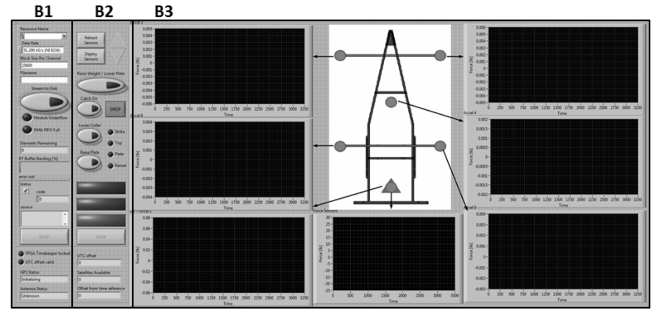

Figure 4: THMPER Control and Acquisition GUI

1.4 Software

The software system of the THMPER system was required to perform three main tasks:

- ***Control:*** The software must interface with the hardware system and provide smooth, reliable operation of the impact source and sensor deployment systems trailer.
- ***Data Acquisition:*** The software must be able to acquire experimental vibration measurements. The measurements must be synchronous and the software design consistent (i.e. scalable) for distributed systems application.
- ***Signal Analysis and Modal Parameter Estimation:*** Once the data is acquired, the software must have the signal processing and modal parameter identification tools to pre- and post-process the raw data and ultimately reduce these experimental observations into actionable metrics (e.g. natural frequencies and mode shapes).

1.4.1 Control and Acquisition

Hydraulic and pneumatic control as well as data acquisition is performed through National Instruments LabVIEW FPGA environment, shown in Figure **??**. The user selects the sampling frequency, block size, and file name (B1) for each data record at each impact location. The user is then able to stream the data to disk locally in a custom binary format (which is later converted to a standard, flat ASCII file) while operating the trailer. Semi-automated control (B2) consists of the ability to raise and lower both the local sensor array and the impact carriage. Additionally, the mass is raised a variable 12”-18”, dropped and autonomously caught by a rebound control system. The mass is then held at apex for 10 seconds to allow an uninterrupted time window for collection of the bridge’s vibration free-decay. Local accelerometers, three load cells, and global stationary reference accelerometers are continuously read and displayed (B3) for complete situational awareness for the user.

1.4.2 Analysis and Archival

Visual Modal Analysis (VMA) is a Graphical User Interface (GUI) program written primarily in Matlab with much of its core functionality compatible with the free equivalent, GNU Octave. It is used to perform digital signal processing and Experimental Modal Analysis tasks and aims to encapsulate the inner workings of the actual analysis so that the user may focus on interpretation.

Upon successful data acquisition at an impact location, the custom software first performs automated data quality checks to vet the data records use for further processing before the trailer is moved to another location. This includes checking for excessive erroneous noise, dropped channels, overloading of the load cells, and proper time synchronization of the independent data acquisitions. Using the pre-processing panel shown in Figure 5, the user is then able to navigate the data for each impact location (D1), average number (D2), and sensor number (D3). The time and frequency force information (D6), response time and frequency information (D7) and spatial information (D5) for each selection is displayed for the user. Next, a series of automated filtering and windowing algorithms (D4) can be applied following the current best practice approaches.

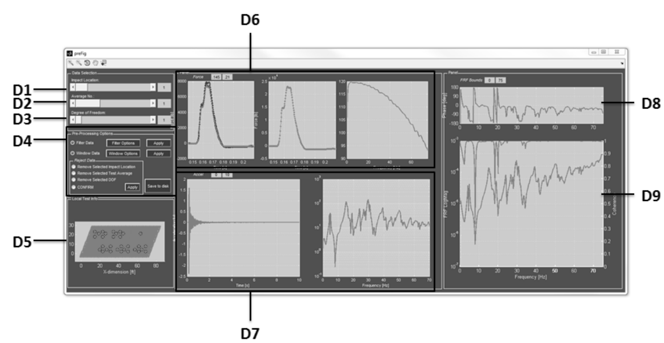

Figure 5: VMA Pre-Processing GUI

The filtering and windowing options are configurable. Filtering typically includes the use of a low-pass Butterworth filter as these filters have low ripple effects within the pass-band. Automated windowing is then performed including a rectangular window on the force signal (utilizing 1/16th cosine taper at the ends of the signal while keeping unity during impact) and an exponential window on the response signals to prevent leak-

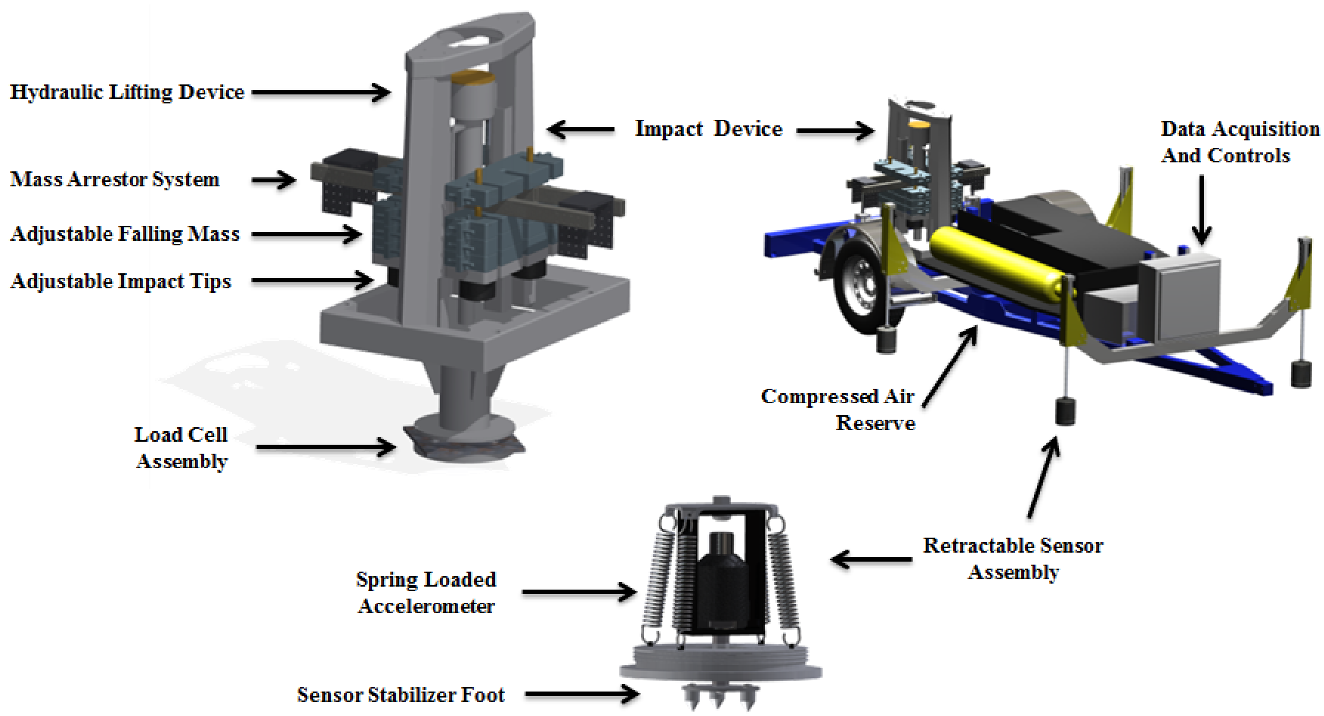

Figure 3: THMPER System Overview

age errors by ensuring the free-decay vibration signal approaches zero at the end of each record. The Frequency Response Function, coherence, and phase (D8/D9) is then autonomously developed and displayed for each degree of freedom (DOF) utilizing the H1 method (as this realistically assumes

Semi-automated modal identification is performed for each impact location via the Complex Mode Indicator Function (CMIF) to extract approximate pole location and mode shapes. CMIF is a spatial domain method typically used for Multi Reference Impact Testing, or multiple-input-multiple-output (MIMO) testing. It is based upon the Expansion Theorem in that it assumes that, at every frequency, the long dimension of the FRF matrix is made up of a summation of modal vectors. The Singular Value Decomposition (SVD) is then utilized to estimate the modal vectors (mode shapes) at each frequency line for each available impact location. The resulting singular values are a measure of dominance of the corresponding modal vector/shape at each frequency line and displayed for each impact location (E2) as well as the selected impact location (E5) with identified candidate peaks. An automated peak picking algorithm identifies and indexes candidate pole locations and corresponding mode shapes. The candidate peak locations are displayed for the user (E1) who is able to scroll through each impact location (E3) and each candidate peak (E4) to display the peak's mode shapes in 3d, plan, and elevations (E8). The user then selects a final set of local pole locations (E6) and assigns global modal rank (E7).

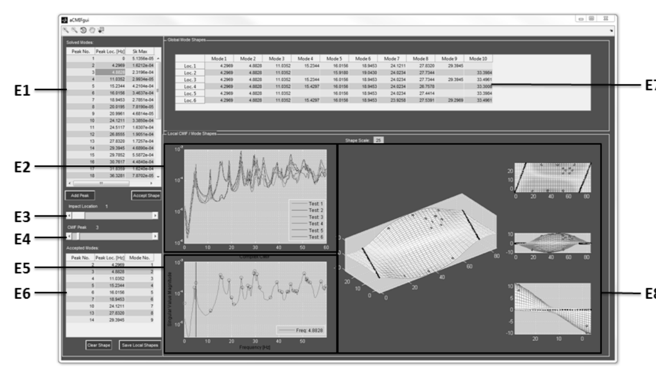

Figure 6: VMA Post-Processing GUI

The approximate pole locations are then passed to an Enhanced Frequency Response Function (eFRF) module. The eFRF is a virtual measurement which uses a single degree of freedom model to identify temporal information (poles and scaling) from the spatial information (mode shapes/modal vectors) for each mode identified in the CMIF. The eFRF is formed by pre and post multiplying the FRF by left and right singular vectors respectively for each mode. This is commonly referred to as performing a 'modal filter' and enhances a particular mode of vibration. A second order Unified Matrix Polynomial Approach is then used to perform a SDOF least squares fit for each mode and accompanying eFRF. This provides a solution to the damped natural frequencies and modal mass of each synthesized SDOF. Each candidate pole location is displayed (G1) where the user can choose the number of shapes to average (G2), the pole average range (G3), and the number of beta terms (G4). The combination of these parameters produces a synthesized eFRF for each mode which is overlaid with the experimentally measured eFRF in real time (G7). Throughout the analysis the full set (for each mode) of eFRF's is displayed to the user for reference (G6). The final set of extracted modal parameters for the master SIMO location is then displayed to the user for final confirmation (G5).

1.4.3 Documentation

Software documentation is important to develop software that is not only maintainable, but is software that people actually use. An example of a configuration README file can be found here: VMA Configuration Files. It describes the configuration files that are used by the software to batch process experimental modal analysis records.

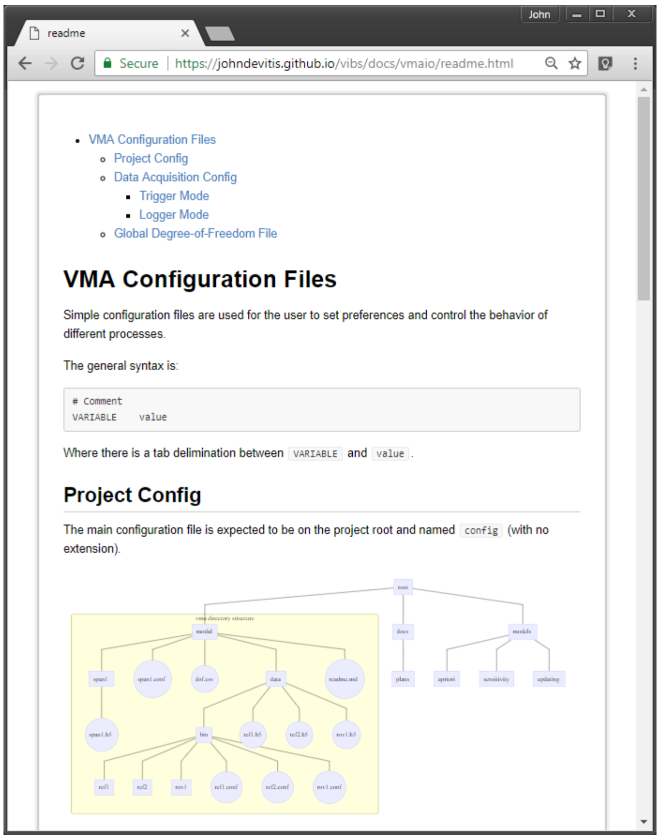

Figure 7: Visual Modal Analysis (VMA) Configuration - README

1.5 Validation

Validation was first performed on a component level to ensure each individual component was within its defined specification. The pneumatically deployed accelerometer housings, for example, were validated by performing a one-to-one signal comparison between each accelerometer housing and reference accelerometer that was glued to the bridge deck (Figure 8).

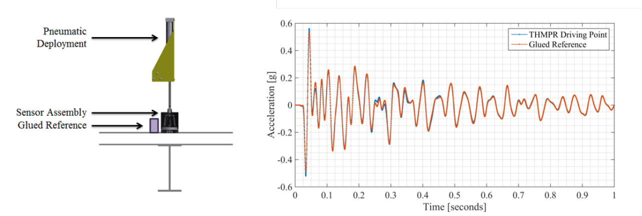

Figure 8: Component Validation - Accelerometer Housing

System level validation was then performed to confirm that the system meets the user's needs and effectively meets the intended purpose defined in the Concept of Operations. The effectiveness of the developed system and test methodology was determined through benchmark field tests using a typical highway bridge located in West Virginia as a case study. This included:

Multi-Reference-Impact-Testing and benchmark Experimental Modal analysis: The system validation plan required the THMPER system be evaluated against the current 'best practices' in forced vibration. An instrumented sledge was used as this benchmark and the estimated modal parameters recovered from each experimental and analytical method were compared.

Diagnostic and Proof Level Truck Load Testing: Truck load testing was used to serve as the ground truth measurements. Global girder displacements and local flange and web strains were acquired, analyzed, and used to calibrate an FE model. Varied load levels and lane configurationos were chosen to examine the linearity of response. A proof load of 300,000 lbs was applied to the bridge to provide maximum flexural response of the girders and compressive strain in the piers.

Figure 9: System Validation - Load Test

Field Calibrated Load Rating: Since the translation between dynamic testing and static load predictions is still a research endeavor, the truck load test and calibrated FE model was used as the ground truth. The modal parameters of each dynamic testing method were used to calibrate an FE model. The FE models were then used to predict displacements due to known truck wheel loads and the responses were compared to the diagnostic and proof truck loading.