RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Anais do 56º Congresso Brasileiro do Concreto
CBC2014
Outubro / 2014

@ 2014 - IBRACON - ISSN 2175-8182

IBRACON

Structural Health Monitoring for the Evaluation of Railroad Bridges

Hani Nassif, Ph.D., P.E., Dan Su, and Peng Lou

Intelligent Bridge Engineering and Advanced Materials (IBEAM) Laboratory
Rutgers Infrastructure Monitoring and Evaluation (RIME) Group

October, 2014

Outline:

- *Introduction*
- *Selected Bridges for Investigation*
- *Finite Element Model*
- *Structural Health Monitoring (SHM) Program*
- *Results and Discussion*

Motivation:

- *Many railroad bridges were built before World War II and are approaching their design life limit, which creates additional concerns.*

- *In New Jersey freight railcars utilize portions of passenger rail system to reach their destinations, sharing lines with NJ Transit commuter rail service. An increase of maximum railcar weight from 263,000-lbs (119 tons) to 286,000-lbs (130 tons) raises concerns for the passenger rail system, since its bridges were not designed for 286,000-lbs (130 tons) cars.*

- *American Railway Engineering and Maintenance-Way Association (AREMA) uses the simple beam analysis to analyze the behavior of the structural member. It doesn't consider the bridge as a structural system and ignores the complex interaction between different member and different boundary conditions.*

Objectives:

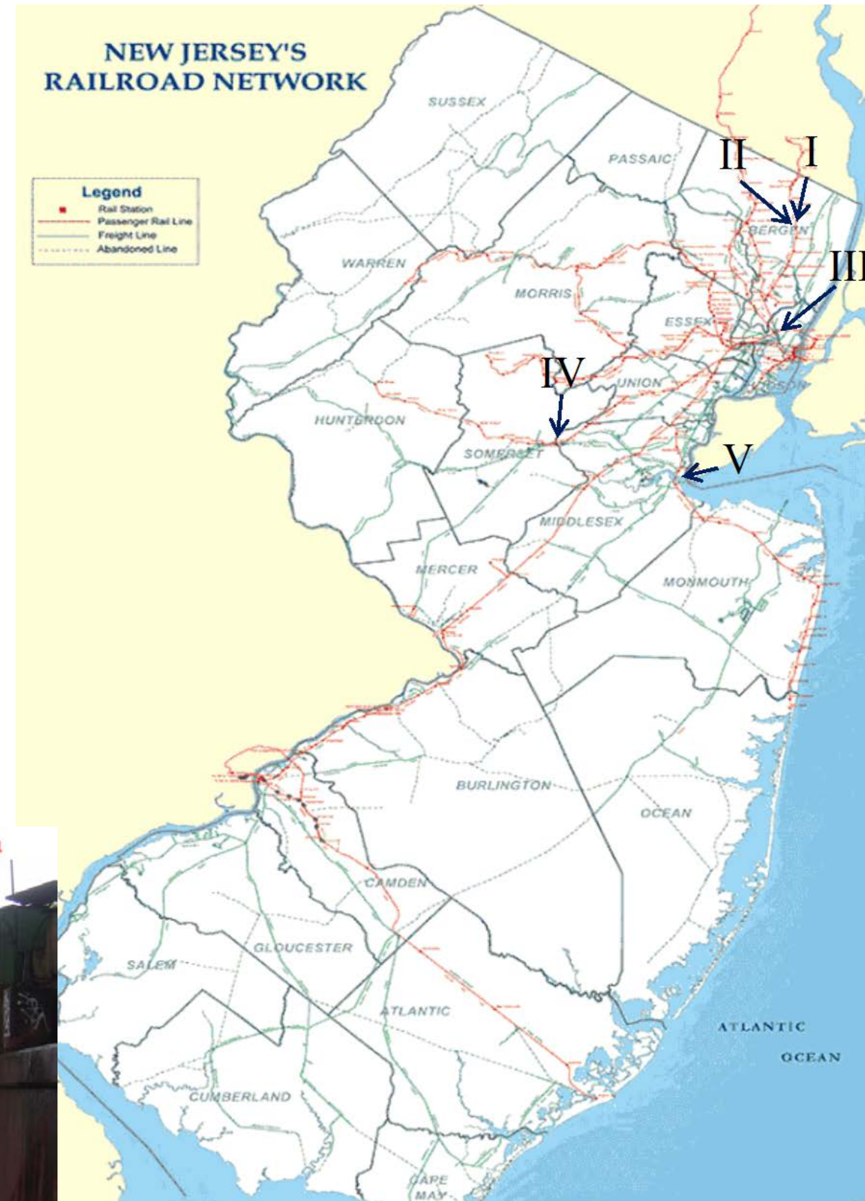
- ***Develop a comprehensive structural health monitoring program to evaluate current conditions of selected railroad bridges in New Jersey to allow travel of 286-kips (130 tons) freight railcar.***

- ***Perform parametric study using validated finite element models.***

- ***Provide general guidelines for bridge evaluation and maintenance.***

Selected Bridges:

1. **Main Line MP 15.95.**
2. **Main Line MP 15.14.**
3. **Bergen County Line MP 5.48 (HX Draw).**
4. **Raritan Valley Line MP 31.15 (Middle Brook).**
5. **North Jersey Coast Line MP 0.39 (River Draw).**

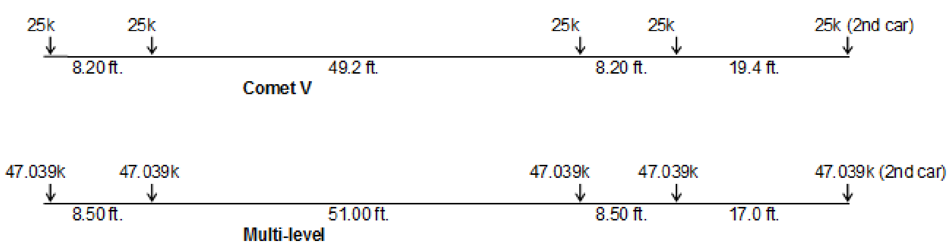


Information of Bridges and Railcars

Information of Selected Bridges

Bridge Name	*Structure Type*
Main Line 15.95	FLB-Girder System with Ballast
Main Line 15.14	FLB-Girder System with Ballast
Bergen County Line MP 5.48	Plate Girder w/o Ballast
Raritan Valley Line MP 31.15	Plate Girder w/o Ballast
North Jersey Coast Line MP 0.39	Plate Girder w/o Ballast

6 different types of locomotives with GVW ranging from 207.2 kips to 292 kips



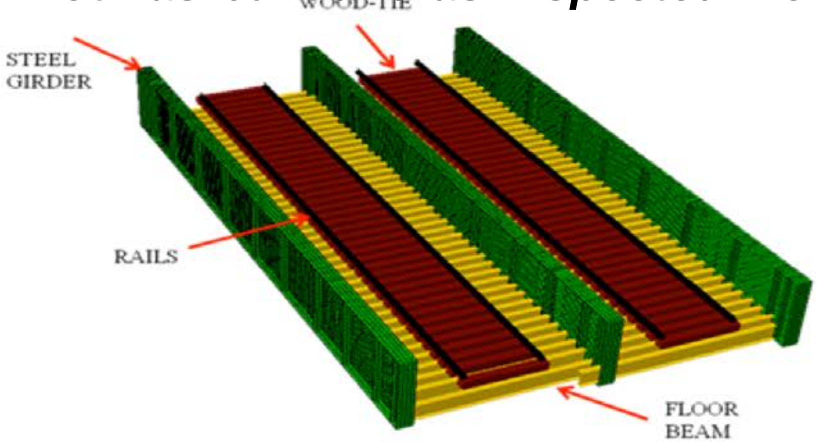
Configuration of Passenger Cars

Configuration of rail cars (ft)

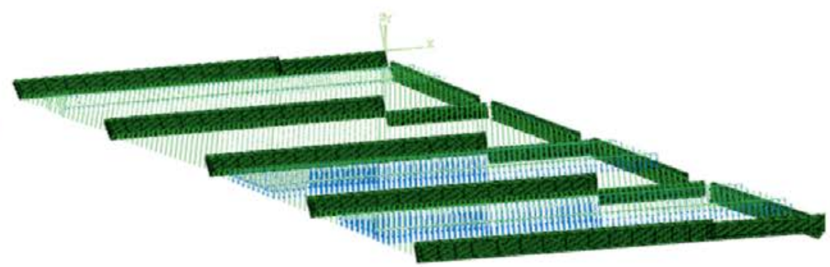
Train type	Rail cars configuration (ft)
GP40-PH-20 locomotive	73 K, 73 K, 73 K, 73 K, 2nd car; 9.0, 28.2, 9.0, 16.17
GP40-PH-2B locomotive	71 K, 71 K, 71 K, 71 K, 2nd car; 9.0, 28.2, 9.0, 16.17
GP40-FH-2M locomotive	70.6 K, 70.6 K, 70.6 K, 70.6 K, 2nd car; 9.0, 28.25, 9.0, 16.17
PL42AC locomotive	72 K, 72 K, 72 K, 72 K, 2nd car; 9.5, 33.8, 9.5, 17.0
F40-PH-2 locomotive	65.4 K, 65.4 K, 65.4 K, 65.4 K, 2nd car; 9.0, 24.0, 9.0, 14.17
ALP-46(A) locomotive	51.8 K, 51.8 K, 51.8 K, 51.8 K, 2nd car; 8.7, 27.23, 8.7, 19.4
AREMA conference 286 K freight car	71.5 K, 71.5 K, 71.5 K, 71.5 K, 2nd car; 5.8, 21.5, 5.8, 6.08

Finite Element Models for Various Bridges

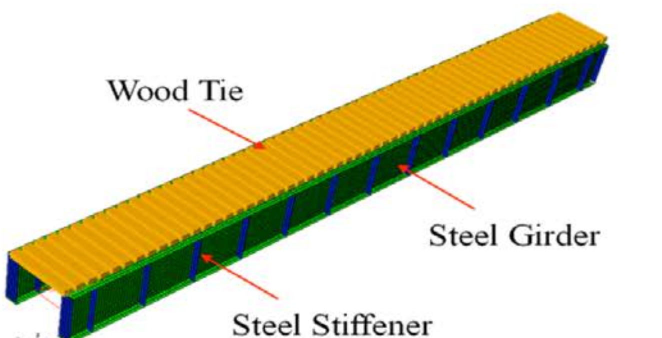
- ***Steel girders and stiffeners were modeled using shell elements***
- ***Diaphragm and diagonal bracing members were also modeled as truss elements***
- ***Wood ties were modeled using beam elements***
- ***Both as-built and as-inspected models were developed***



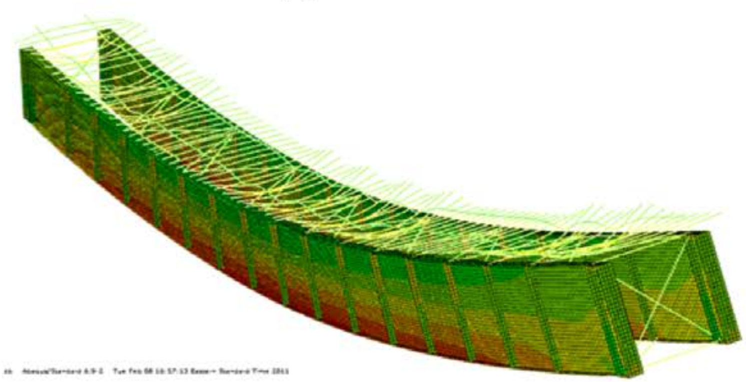
(a)Main Line MP 15.95



(b) Main Line MP 15.14



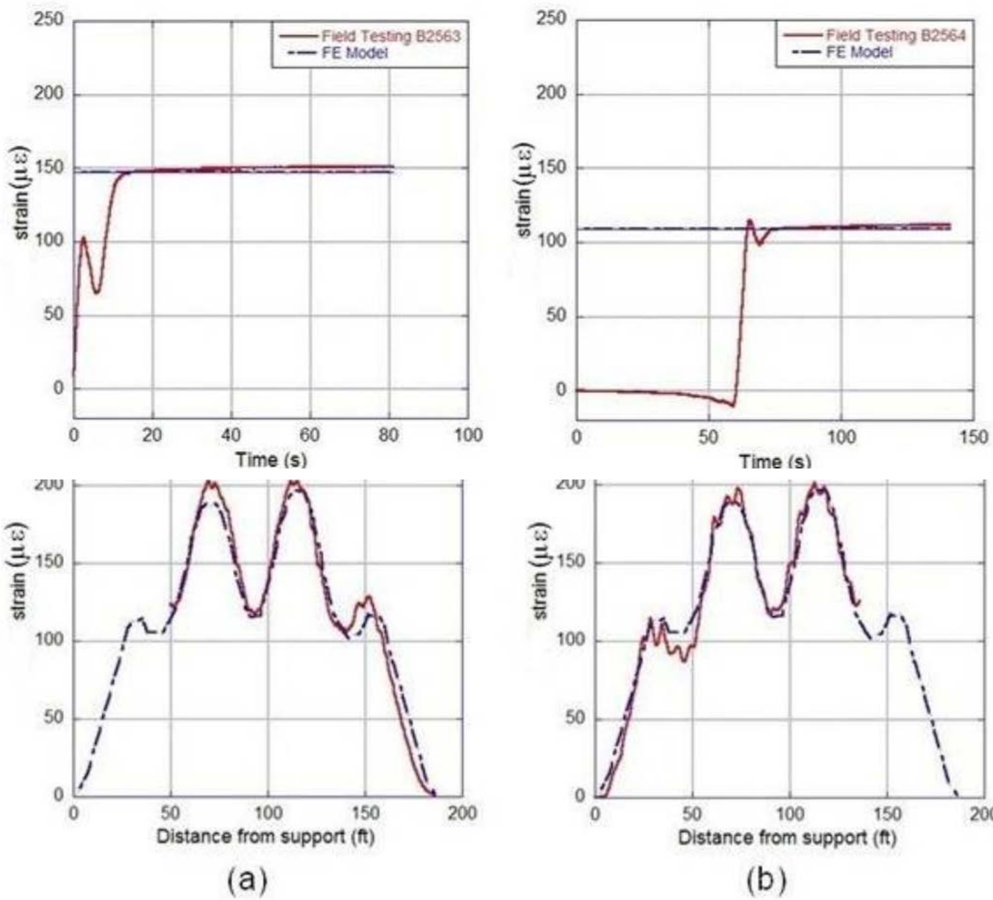
(c) Bergen County Line MP 5.48



(d) North Jersey Coast Line MP 0.39

Validation of Finite Element Models

- ***The finite element models for various bridges were validated using dynamic and static testing data.***
- ***The boundary conditions and/or connections between different members were adjusted to reach better agreement with the experimental data.***

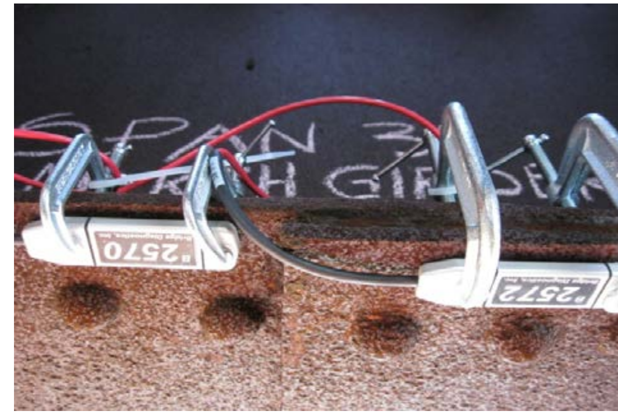


Comparison of Tensile Strain between Static Field Testing Data and FE Analysis Result, Bergen County HX Draw Bridge

Comparison of Tensile Strain between Dynamic Field Testing Data and FE Analysis Result, Bergen County HX Draw Bridge

Objectives and Equipment

- *Obtain structural response (strain and deflection) under static and dynamic loading.*
- *Evaluate the performance of the bridges under freight and passenger railcar loading*
- *Validate and calibrate the FE model.*



- *Strain Transducer*

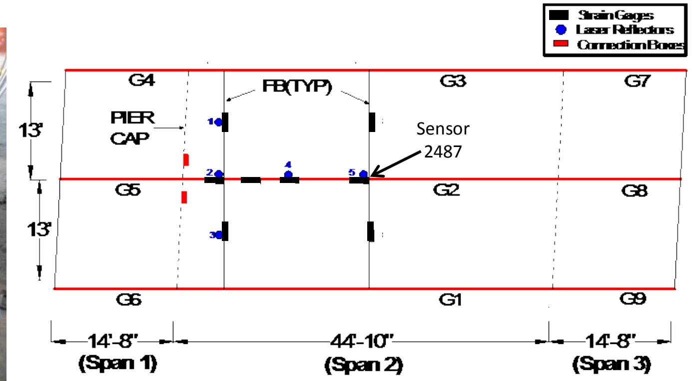
- *Laser Doppler Vibrometer*

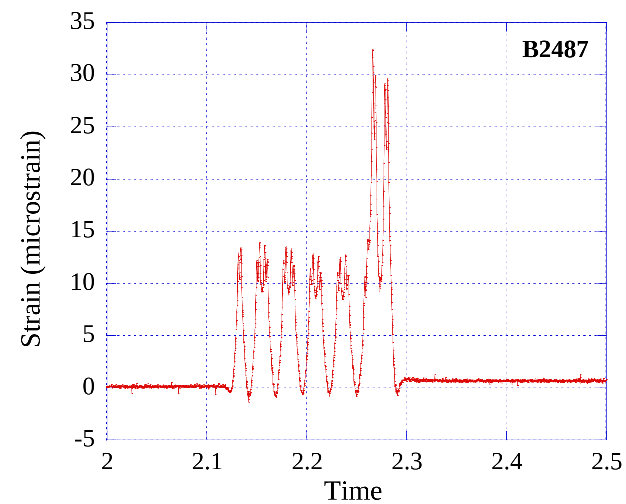
- *Reflective Tapes on Bridge Elements*

- *Wireless Data Collection System*

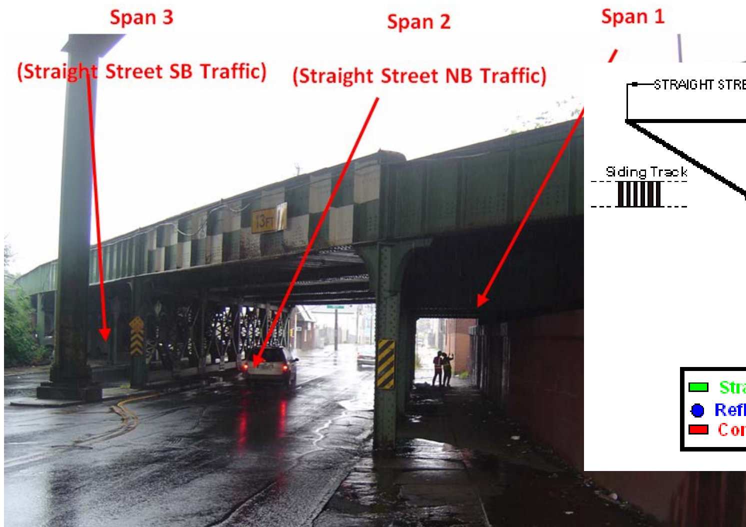
Data Collection under Live Load

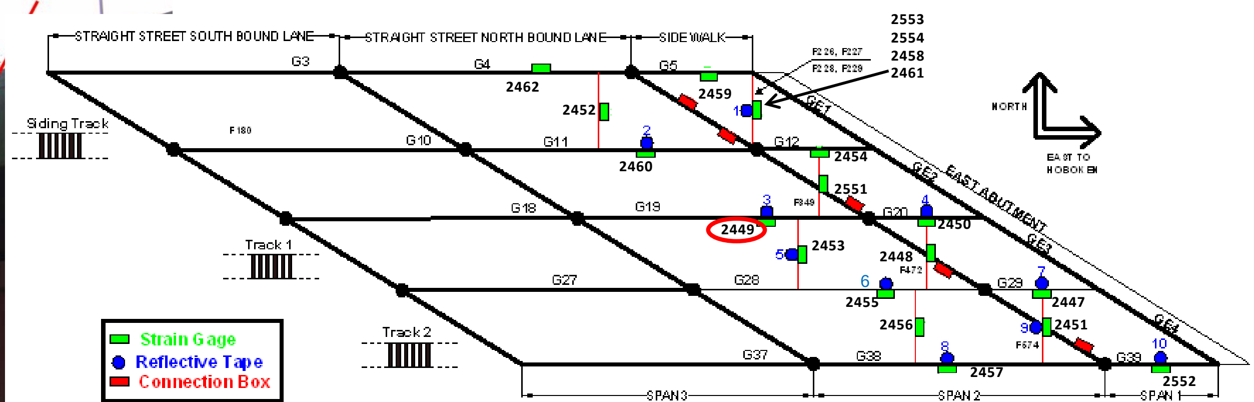
Bridge I: Main Line MP 15.95

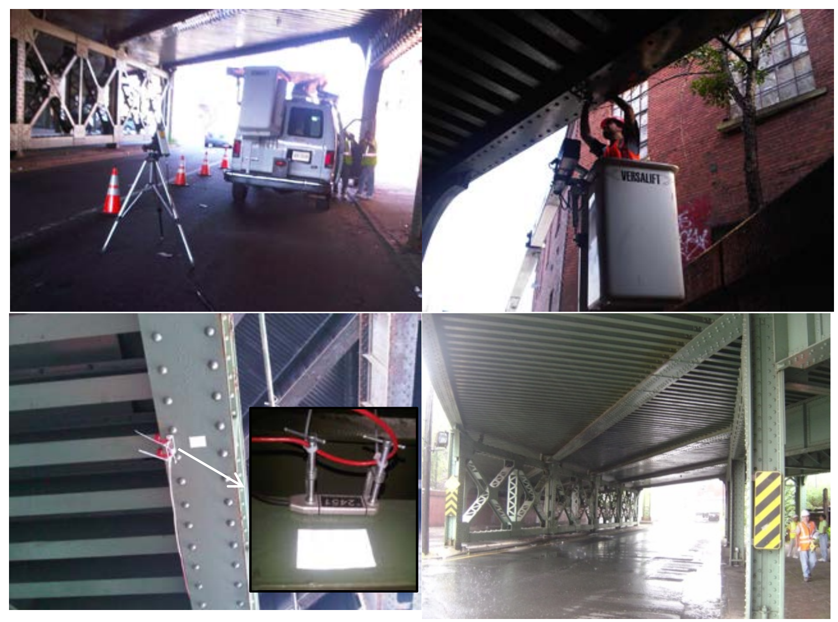




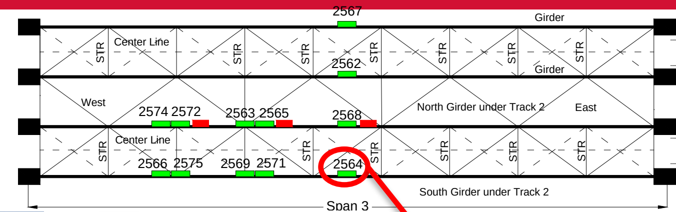
Bridge II: Main Line MP 15.14

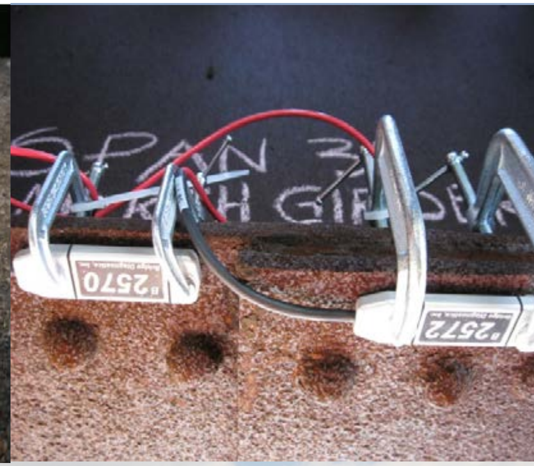


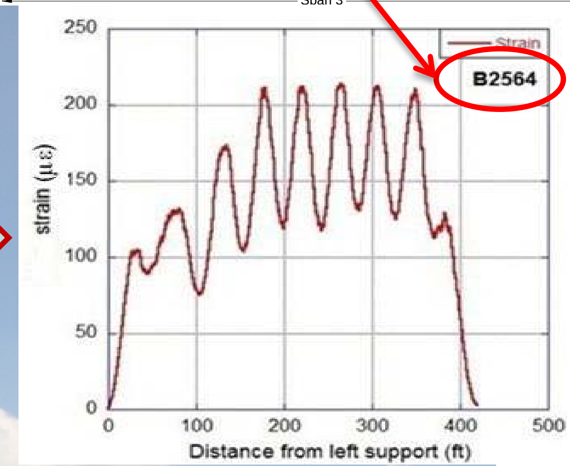




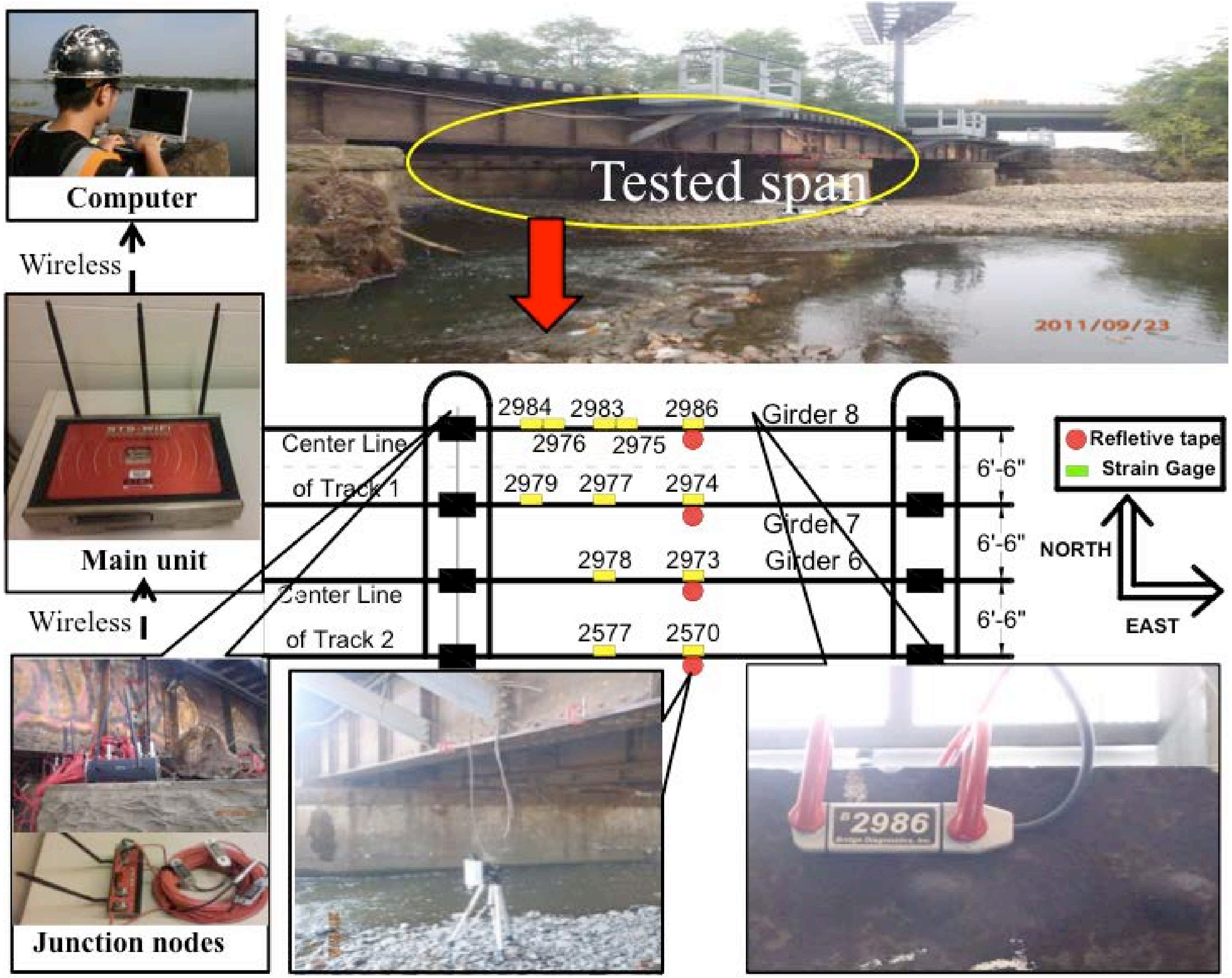
Bridge III: Bergen County Line MP 5.48 (HX Draw)

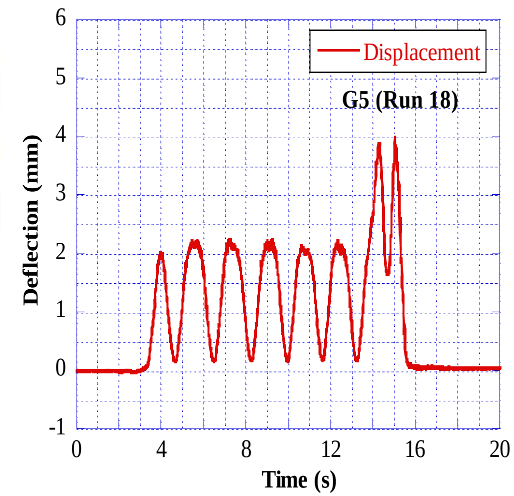




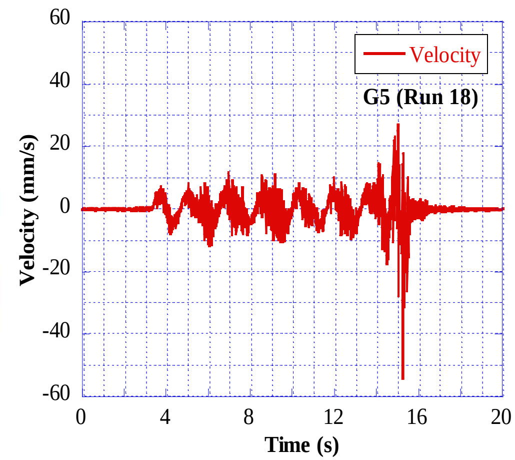


Bridge IV: Raritan Valley Line MP 31.15 (Middle Brook)



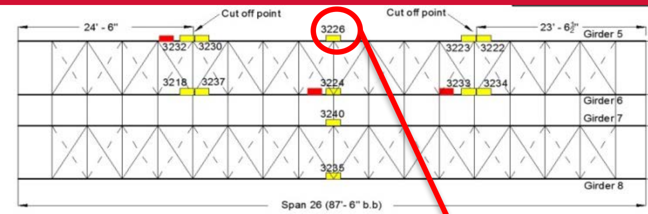


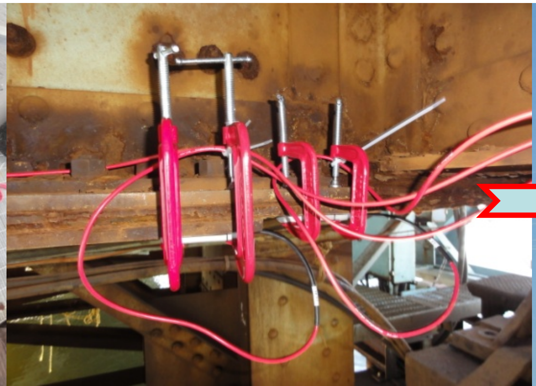
- ***Deflection***



- ***Velocity***

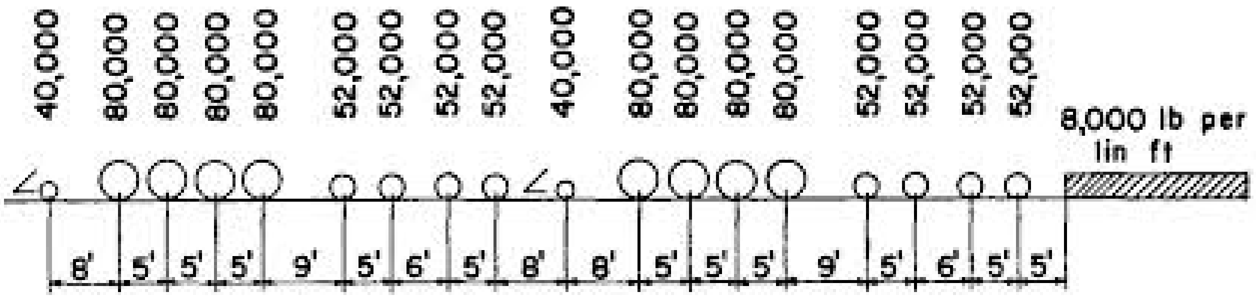
Bridge V: North Jersey Coast Line MP 0.39 (River Draw)





Basic Method: Traditional Method Based on AREMA Manual

Currently, the railway bridges are evaluated using load rating method recommended by American Railway Engineering and Maintenance-Way Association (AREMA).



Cooper E 80 Axle Load Diagram

Two types of rating: Normal rating refers to the load level that can be carried by the expected life of the bridge. Maximum rating refers to the load level that can be carried at infrequent intervals.

Basic Method: Traditional Method Based on AREMA Manual

***Pros*:**

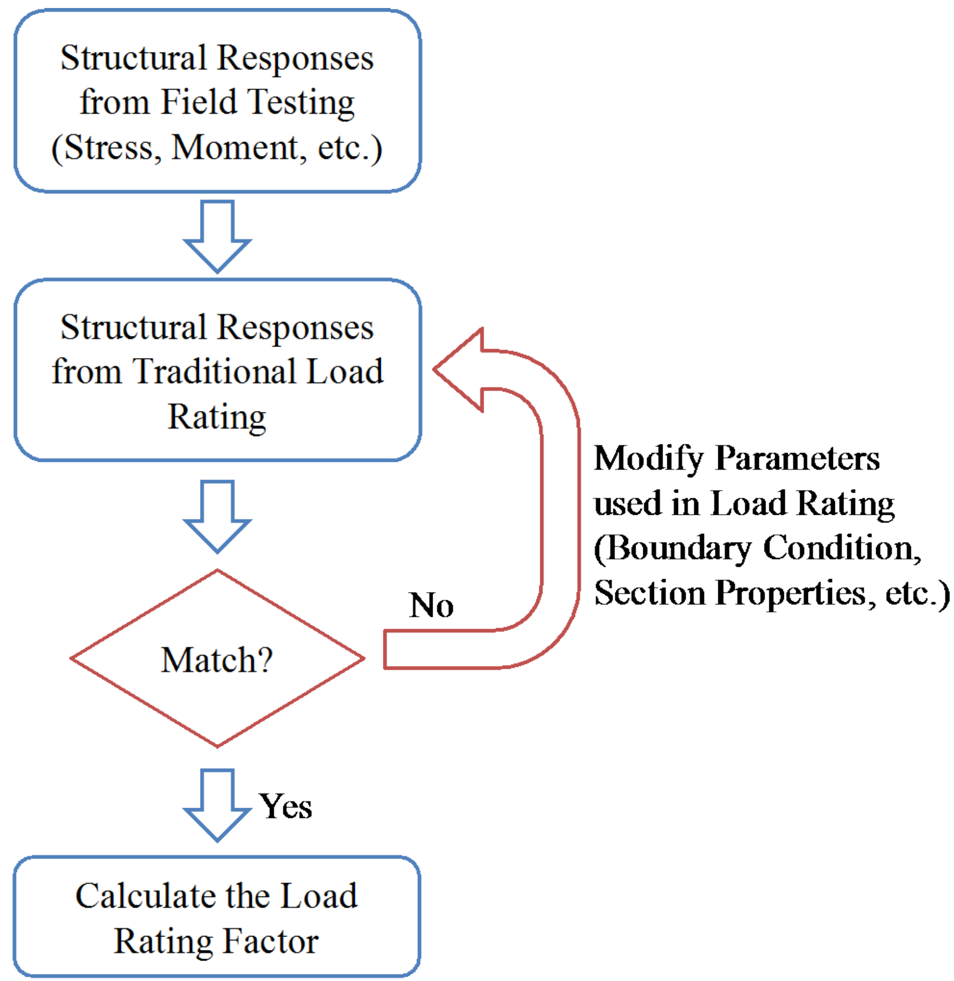
- **Easy to use, no complicated calculated involved**
- **Familiar to the designers, engineers and other practitioners**

Cons:

- **Utilize simple structural analysis without considering the structure as a complicated system (with and w/o ballast)**
- **The input information might not accurate since the detailed inspection is conducted every 5 or 6 years.**
- **No long term evaluation provided.**

Refined Traditional Method based on SHM and FE Modeling

3-D FE model considers different boundary conditions and complex interaction between different members and it was calibrated using experimental data collected from field. Therefore, FE modeling can be used to precisely predict the load capacity of the complex structure.



Refining Process of Traditional Load Rating Method

Bridge Evaluation Results

Line	Mile Post	Rating Level	Rating (AREMA) (1)	Rating (Refined Method) (2)	% Difference (1) vs. (2)
Main Line	15.95	Normal	E-53	E-388	632%
		Maximum	E-85	E-571	572%
Main Line	15.14	Normal	E-52	E-75	44%
		Maximum	E-92	E-136	48%
Bergen County Line	5.48	Normal	E-27	E-45	67%
		Maximum	E-43	E-69	60%
Raritan Valley Line	31.15	Normal	E-55	E-64	16%
		Maximum	E-83	E-97	17%
North Jersey Cost Line	0.39	Normal	E-50	E-64	28%
		Maximum	E-80	E-103	29%

Possible reasons that caused the differences between two methods:

(1) Simplified boundary conditions in the rating using AREMA approach.

(2) Conservative estimation of section losses in the rating using AREMA approach.

(3) Out of date structural information was used in the inspection report.

Results and Discussion

Based on the analysis results of this study, the following conclusions can be drawn from the results:

1) The traditional load rating method specified by AREMA uses the simple beam analysis to analyze the behavior of the structural member. It does not consider the bridge as a structural system and ignores the complex interaction between different members and different boundary conditions.

2) If using AREMA approach to load rate the bridge, instead of using simple supported uniformly, the boundary condition might need to be revised to represent the real condition of the bridge. The field testing is recommended to validate the boundary condition of the bridge.

3) A refined traditional load rating method can provide accurate evaluation results efficiently. The refining process is based on field testing data by applying several trail-and-error processes. Various parameters such as boundary conditions and section properties might need to be adjusted during the refining process.

Acknowledgements

- ***NJ TRANSIT: Chuck Maliszewski, Chief Engineer, David Dieck, Director, Contract Administration – Rail Operations, and Paul Falkowski, Project Engineer***
- ***Conrail***
- ***NJDOT Staff: Edward S. Kondrath, Project Manager, Dominick Critelli and Miki Krakauer - NJDOT Rail Services.***
- ***Yingjie Wang, Post-Doctoral Fellow. Zeeshan Ghanci, and Khalid Machich, undergraduate students***
- ***Ope Adediji, Ufuk Ates, Tim Walkowich, Former Research Assistants, Rutgers University.***
- ***Meghan Valeo, Michael Colville, and Rohit M. Patel, Arora and Associates, P.C.***
- ***Passaic County Traffic Bureau and Police Officers***