Finite Element (FE) Modeling of Century Old Tilton-Belmont Railroad Bridge in New Hampshire Under Typical Train Loading

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Introduction

- Most railroad (RR) bridges in the U.S. built in the late 19th and early 20th century;
- To extend life of these critical transportation assets, effective and efficient Structural Health Monitoring (SHM) techniques needs to be implemented

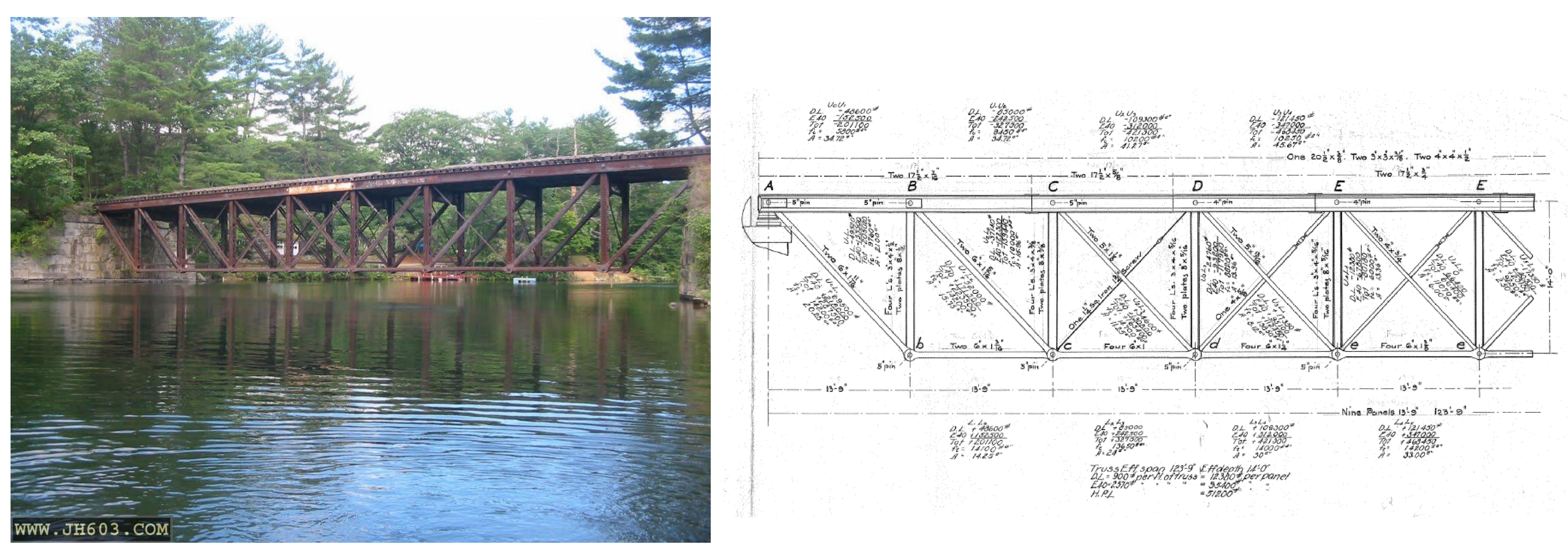

Fig. 1: Tilton Belmont New Hampshire Bridge, Image (left), As-built side view (right)

Objectives

With a large number of bridges in the United States approaching the end of their design service life, the primary goal of this research is to develop a strong and economically viable system for evaluating structural health through the use of cost-effective approaches. Tilton-Belmont Railroad Bridge, which was constructed in 1893 and is situated in New Hampshire (NH), was utilized as a representative bridge. This bridge is a single-span railroad steel bridge with an open deck truss and consists of a single railroad track. This bridge is traversed by passenger and freight trains occasionally.

Specific Presentation objectives:

- To develop the finite element model of the Tilton-Belmont New Hampshire bridge (Fig. 1) using the as-built drawing;
- To conduct the modal analyses of the bridge and determine their dynamic characteristics such as natural frequencies and different mode shapes
- To determine the displacement of the bridge under freight train

Methodology

The 3D bride span model of the Tilton-Belmont bridge (length: 123.75'; width:12'; height:14') was created using 483 members in wire elements, with 33 different cross-sections, such as eyebars, stringers, floor beams, and diagonals. Fig. 2 presents the 3D rendered view of the bridge modeled in the ABAQUS CAE 6.19 software.

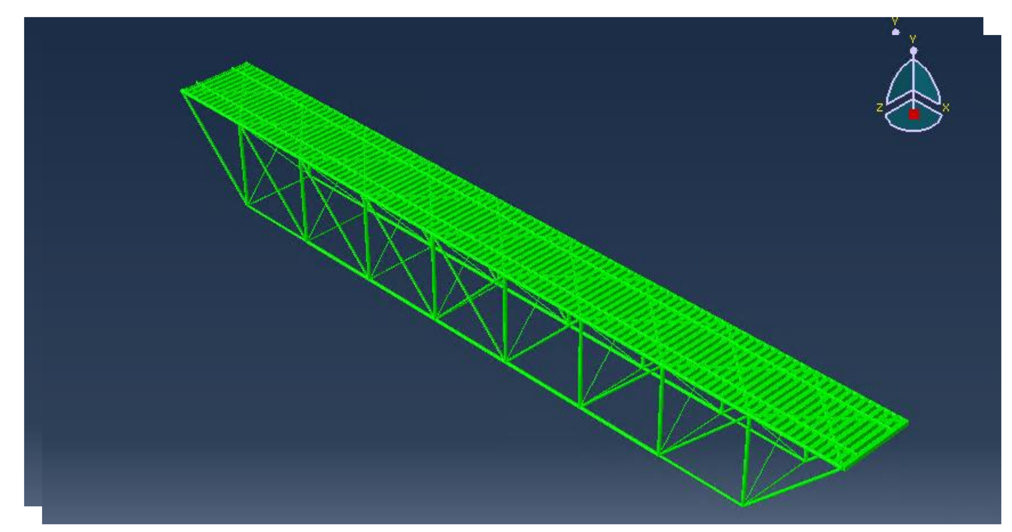

Fig. 2: Rendered View of 3D FEM Wire model Tilton Belmont Bridge

- Parts were based upon 1893 as-built drawings;
- Total Elements: 736 out of which 644 are linear line elements of type B31 (two-node beam elements) and the remaining 92 are linear line elements of type T3D2 (2-node truss element)
- Beam Elements (B31); Top Chord, Rails, Ties, Stringers, Floor Beam
- Truss Elements: Bottom Chord, Diagonals, Sway Bracing, Lateral Bracings
- Boundary Conditions: Simply Supported (Hinge and Roller)

Once the basic FE model was developed, modal analyses were conducted. Subsequently, static analyses were done to determine the vertical displacements at different points on the bridge. The standard 4-axle car configuration (Fig. 3) for bridge rating provided by NHDoT has been used to conduct static analyses for four different conditions i.e., when freight train with cars of 263000lbs covers a)1/4th part; b)1/2 part; c)3/4th part and d)full part of the bridge.

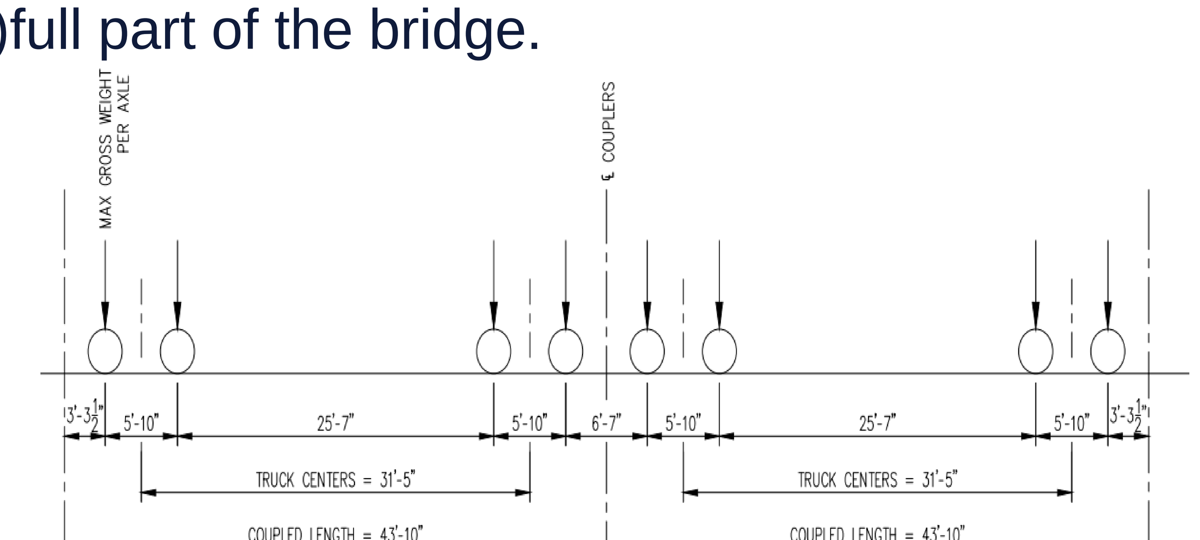

Fig. 3: Standard 4-axle Car Configuration for Bridge Rating

Results and Discussion

Modal Analyses (Natural Frequencies and Mode shapes)

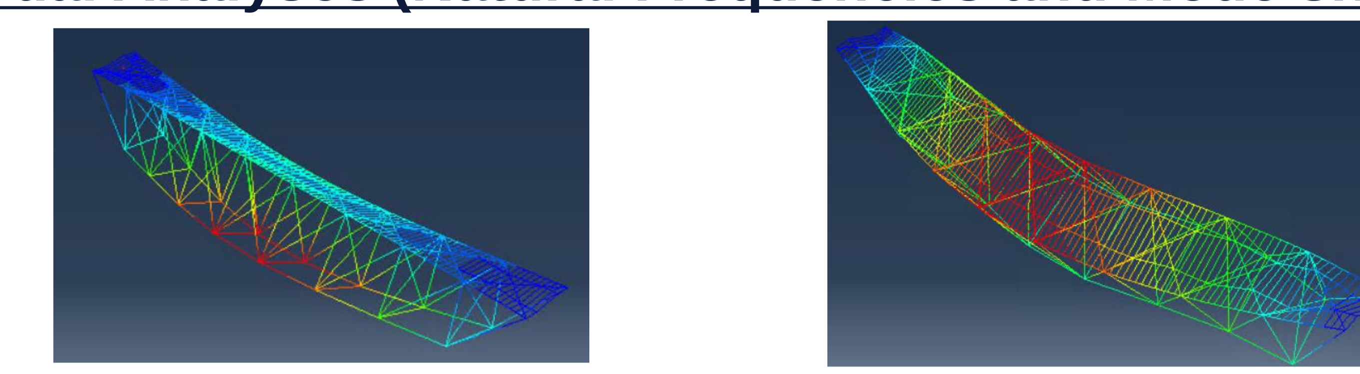

Fig. 4: First Lateral Mode Shape (1.0 Hz, Left); Second Lateral Mode Shape (1.9 Hz, Right)

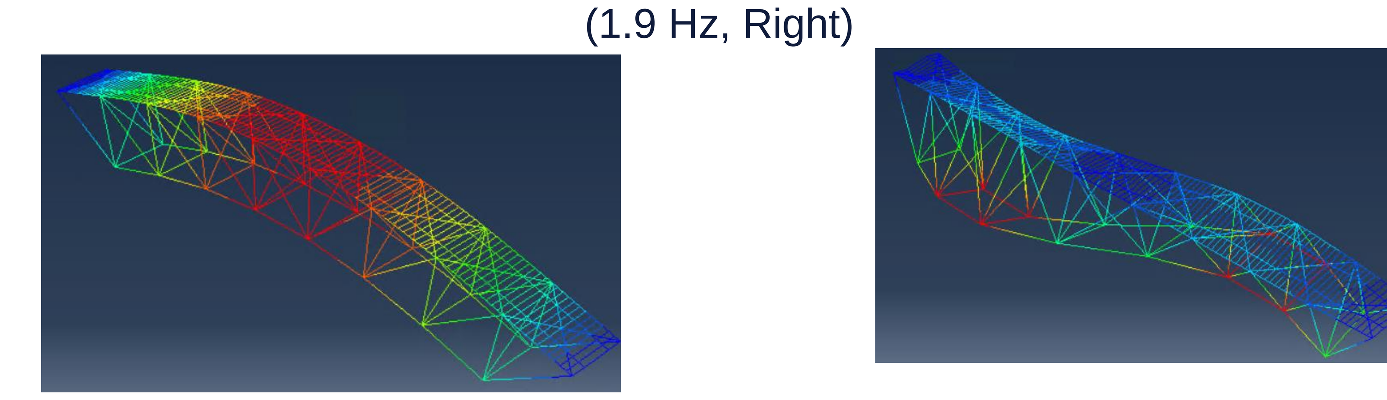

Fig. 5: First Vertical Mode Shape (1.2 Hz, Left); First Twisting Mode Shape (2.0 Hz, Right)

Vibration Mode	FE Natural Frequency (Hz)
1st Lateral	1
1st Vertical	1.2
2nd Lateral	1.9
1st Twisting	2
3rd lateral	2.4
4th Lateral	2.6
2nd Vertical	3

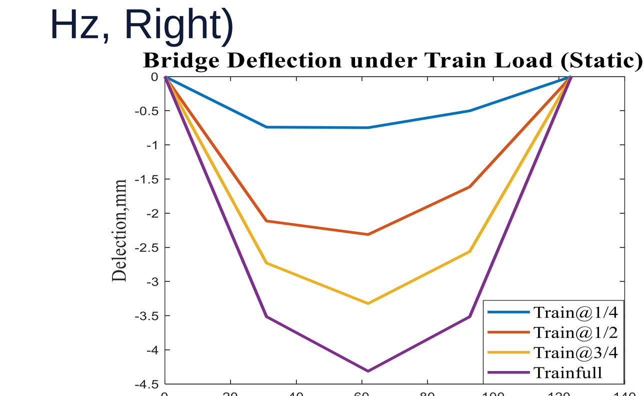

Fig. 6: Vertical displacement on the bridge when train is at ¼ , ½, ¾, and fully covered condition (Max Deflection: 4.32 mm)

Conclusions

The preliminary FE model has been developed and is under the process of refinement. The dynamic characteristics of the bridge have been determined conducting modal analyses, and vertical displacements at different locations on the bridge under freight train were determined using static analyses.

Acknowledgments

We would like to thank US DOT Region 1 UTC - Transportation Infrastructure Durability Center (TIDC) under grant 69A3551847101 from the U.S. Department of Transportation's University Transportation Centers program and the University of Connecticut for supporting the project financially. We would also like to extend our deepest gratitude to the other supporting organizations listed below.