Methodology to Transfer Global Response to Local Model Using Finite Element Model and Field Test of Two Connecticut Steel Truss Railroad Bridges

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Introduction

Most railroad bridges in the United States were built in the late 19th and early 20th century using outdated design codes and technology. Although those bridges still operate under periodic inspections and enforced rating plans, they often exhibit an unusual dynamic response due to wear and tear owing to their old age.

Objectives

With the approaching life expectance of most bridges in the United States, it is crucial to establish a methodology to evaluate the structural condition of existing bridges using cost-effective techniques. Hence, it is essential to have a better understanding of the bridge's behavior. This study aims to comprehend the critical connection of the local members of the two CT railroad bridges, Cos Cob Bridge (Figure 1) and Devon Bridge (Figure 2), under passenger train loads. These two bridges are part of the Northeast Corridor, which is the busiest rail corridor in the US.

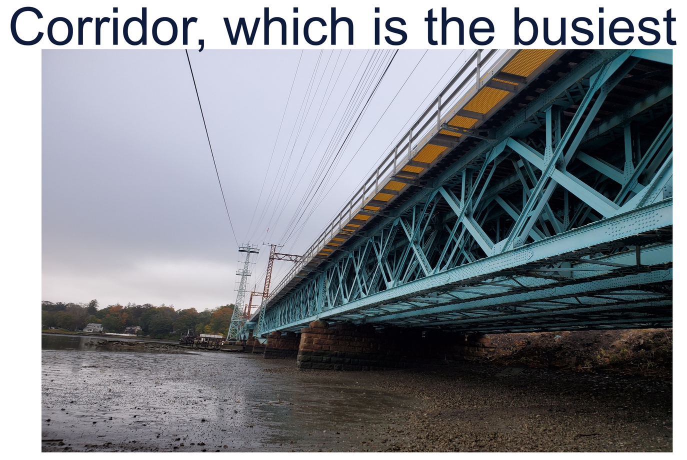


Figure 1: Cos Cob Bridge, Greenwich, CT (Built-in 1904; Span 3 length: 122'-10"; Height: 15'; Track 4 Width: 7'-6"; Total no. of Tracks: 1)

Figure 2: Devon Bridge, Stanford/Milford, CT (Built-in 1906; Span 7 length: 217'-7"; Height: 40'; Width: 30'-10"; Total no. of Tracks: 2)

Methodology

This study presents the principle to understand the transfer of the global response of the bridge span to a local detailed FE model. Starting by comparing the field test results with the numerical model, the Global FE model. Next, the displacement and rotation from the Global model were transferred to the detailed localized FE model using St. Venant's principle. The field tests for these bridges focused on using a Laser Doppler Vibrometer (LDV) and accelerometers as references (Figure 3). The FE model was created using ANSYS Workbench® to replicate span 3 (track 4) of the Cos Cob bridge and span 7 of the Devon bridge (Figure 4), both open-deck trusses. A series of triangular step forces with a specific spacing has been used to represent different types of vehicles. Finally, the information from the global model was transferred to a detailed local model. The global model was generated using a wire element, whereas the local is solid.

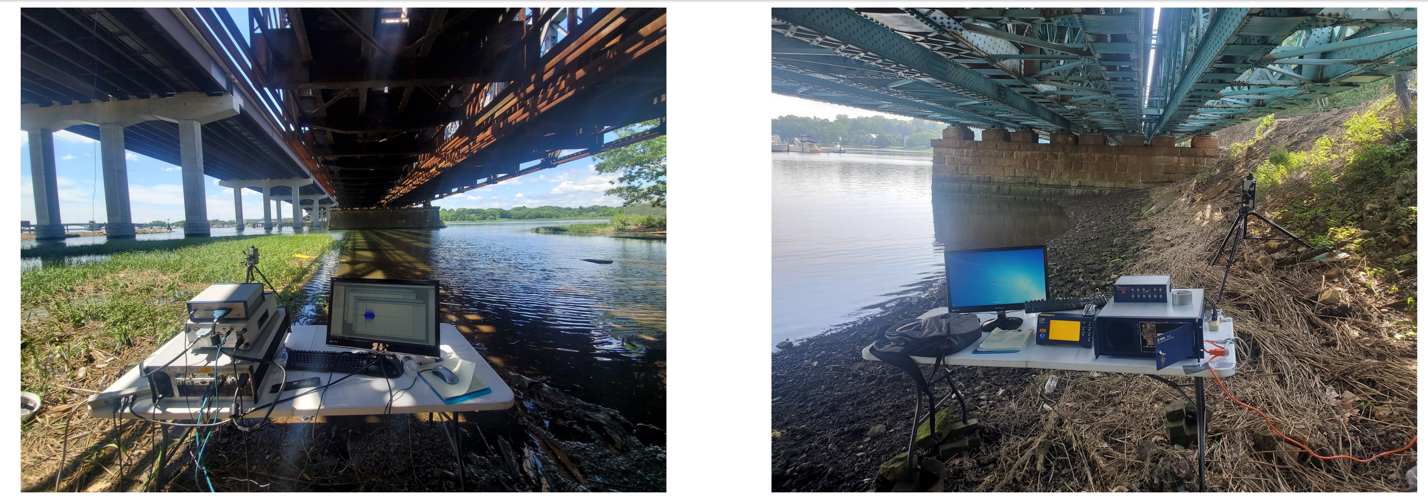


Figure 3: Field test setup, Devon Bridge (left), Cos Cob Bridge (right)

As per the project's approach, Finite Element Analysis (FEA) was employed to validate the results obtained from the field tests concerning the frequency and time domains. The analysis primarily relied on two models, as shown in Figure 4. These models were instrumental in determining the displacement of specific aspects in response to forced vibrations of varying frequencies, measured in Hertz (Hz)

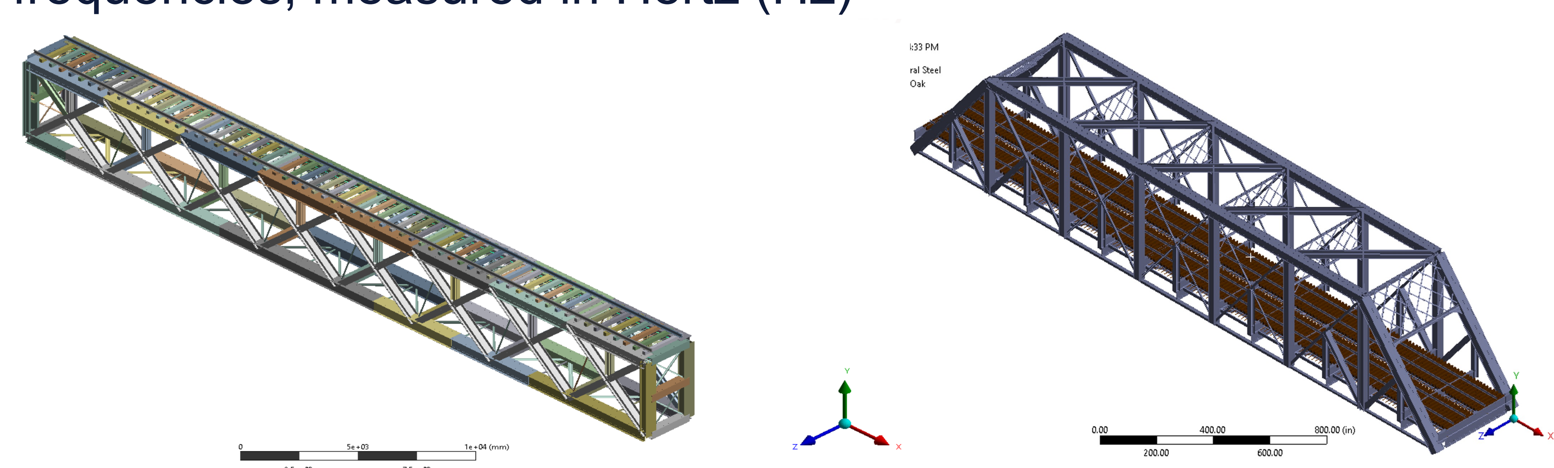
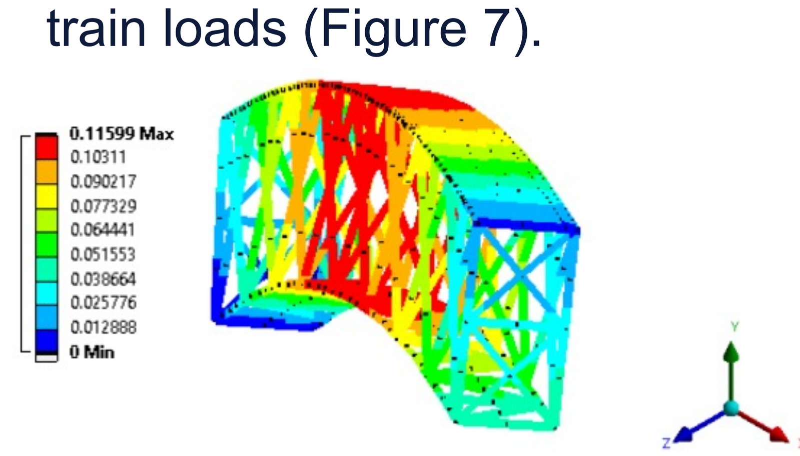


Figure 4: Cos Cob Bridge model (Left) , Devon Bridge Model (right)

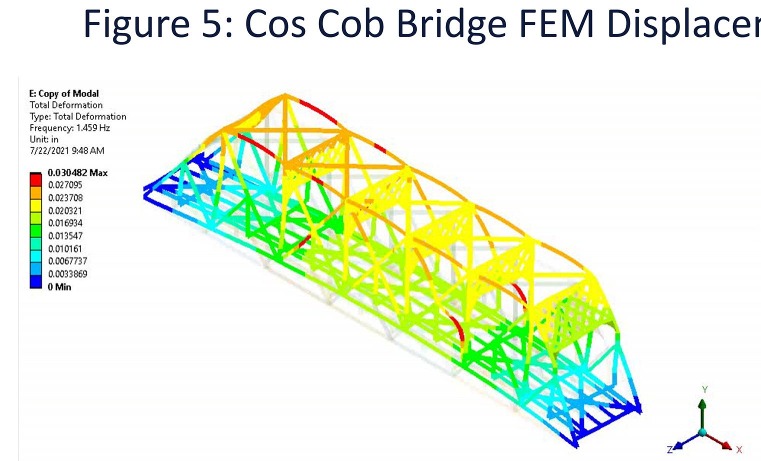
Results and Discussion

A finite Element Analysis of both bridges was performed using ANSYS Workbench to find the mode shapes with their frequencies (Figures 5 and 6) as well as the displacements of the bridges under train loads (Figure 7).



Natural Frequency	Field Test	FE Model
1st Lateral	**3.930**	3.420
2nd Lateral	**9.000**	7.890
1st Vertical	**8.540**	7.540

Figure 5: Cos Cob Bridge FEM Displacement (left), Field Test/FEM Comparison (right)



Natural Frequency	Field Test	FE Model
1st Lateral	**1.783**	1.431
2nd Lateral	**4.125**	3.991
1st Vertical	**4.474**	4.442

Figure 6: Devon Bridge FEM Displacement (left), Field Test/FEM Comparison (right)

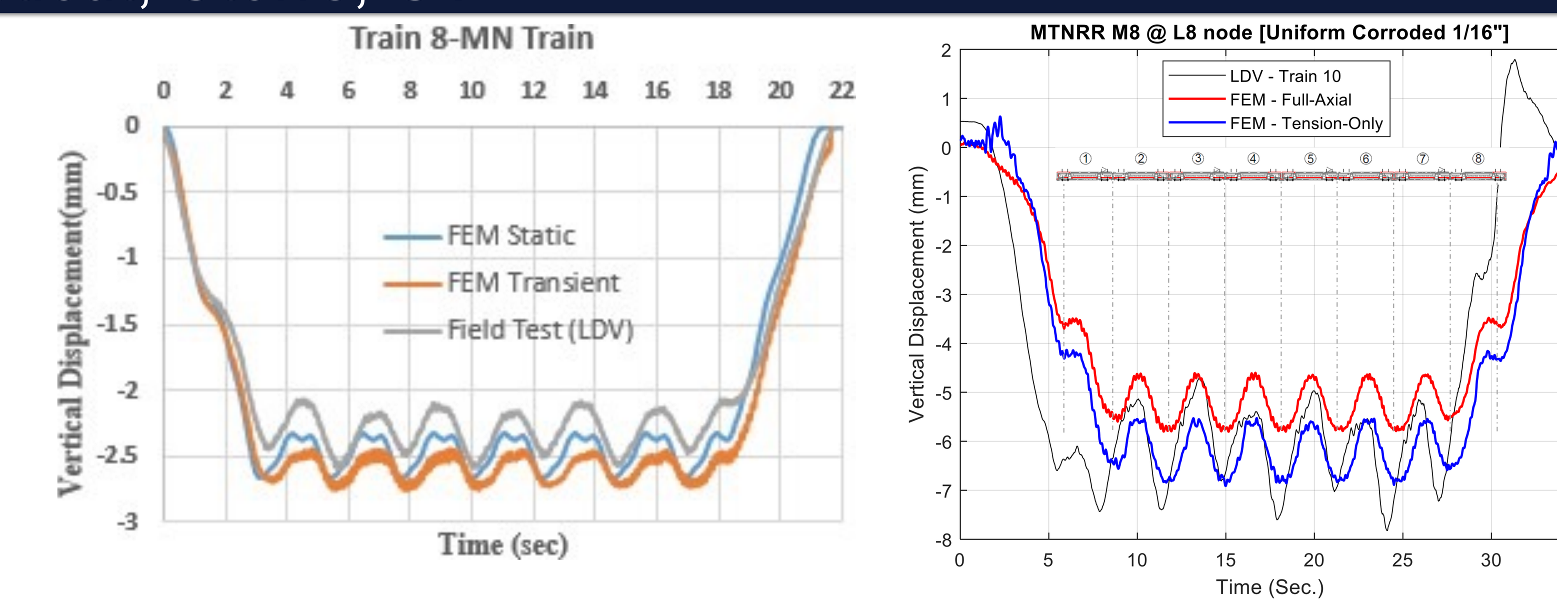


Figure 7: Processed Vertical Displacement of Cos Cob Bridge(left), Processed Vertical Displacement of Devon Bridge(right)

Conclusions

Based on the field test results, it seems that the FEA model could serve as a valuable tool for predicting the behavior of bridges under different loading conditions. By conducting multiple test cases with varying train loadings, it can offer precise insights into the dynamic behavior of older railroad bridges, which is crucial for enhancing safety measures. This underscores the significant potential for academic research in this area.

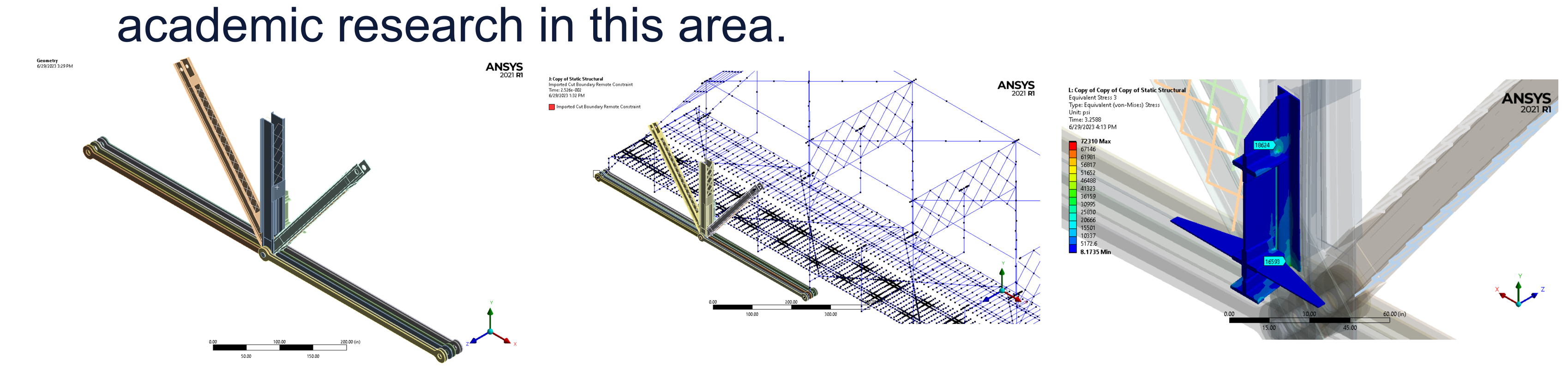


Figure 8: Devon Bridge local model Node L2 – 3D model (left), global to local transfer (center), and von missed stress of local connection (right)

Strain gauges will be installed on selected members to correlate the strain during typical operations. Similar, strain gauges are planned to installed on Cos Cob bridge gusset plates.

Acknowledgments

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