Quarterly Progress Report

Project Number and Title: Project 1.2: Condition/Health Monitoring of Railroad Bridges for Structural Safety, Integrity, and Durability

Research Area: Thrust 1 -Transportation Infrastructure Monitoring & Assessment for Enhanced Life

PI: Ramesh B. Malla, Ph.D., F. ASCE, F. EMI, Professor, Department of Civil & Environmental Engineering, University of Connecticut, and **Institutional Lead** for US DOT Region 1 UTC-TIDC Program

Co-PI(s): N/A

Reporting Period: April 01, 2021 to June 30, 2021

Submission Date: June 30, 2021

Overview:

Brief overview and summary of activities performed during the reporting period:

During this reporting period, the research team has performed a field test of the two railroad bridges, Devon bridge located over the Housatonic River between Milford and Stratford, CT, and the Cos Cob bridge located over the Mianus River between Cos Cob and Riverside, CT. The data collected using Single Point Laser Vibrometer was partial analyzed and determined the natural frequencies of the bridge structure, and displacement of selected node under service load. These dynamic parameters will be further verified and compared using Finite Element Modeling (FEM). The FEM model from the selected bridges, Devon and Cos Cob, is almost calibrated. The research team has been preparing samples and specimens for further material characterization. The research team has been active in publishing and presenting the findings from the research.

Given below is a summary of activities performed by the research team during this quarterly report period:

- A field test on Cos Cob bridge was conducted on June 06, 2021 and June 07, 2021 (Figure 1). For this test, the research team used Single Point Laser Vibrometer to collect the dynamic response of the bridge under moving train (Figure 2). The Polytec Inc. supported the research team with the Single Point Laser Vibrometer, and the Metro-North RR and ConnDOT supported the research team with logistic during the testing.
- Similar field test was conducted on Devon bridge on June 08, 2021(Figure 3, 4). The research team received similar assistance from the Polytec Inc., the Metro-North RR, and ConnDOT
- The preliminary analysis on collected data using Single Point Laser Vibrometer on both Cos Cob and Devon bridges has been done, and the Natural frequencies of the bridges and the time-domain displacement response of each selected nodes under moving train are identified.
- Significant progress has been made in modeling the Devon and Cos Cob bridge for FEM analysis. The FEM model of a Devon bridge is complete and under calibration using time-domain displacement response collected on the field test mentioned above (Figure 5, and 6).
- The research team resumed working on material characterization with the metallographic test. New samples are being prepared for the tensile, fractography and the hardness indentation test. The research team will start these testing as soon as the samples are ready.
- The research team welcomed one undergraduate student into the team for the summer who will be helping in the field test, laboratory test, FEM modeling and the dynamic analysis.
- The research team continues to maintain close collaboration with the government and industry companies, such as Conn DOT, Metro-North RR and Polytec Inc.
- The research team has presented a recorded video at TIDC Showcase Presentations with the title “Field Testing and FE Modeling of Selected Truss Railroad Bridges in Connecticut” on May 19, 2021.The research team presented a recorded video at International Bridge Conference with the title “Monitoring and Dynamic Response of Two More than Century Old Truss Railroad Bridge “on June 11, 2021.

Figure 1 – Cos Cob Bridge: Horizontal reading vibrometer setup

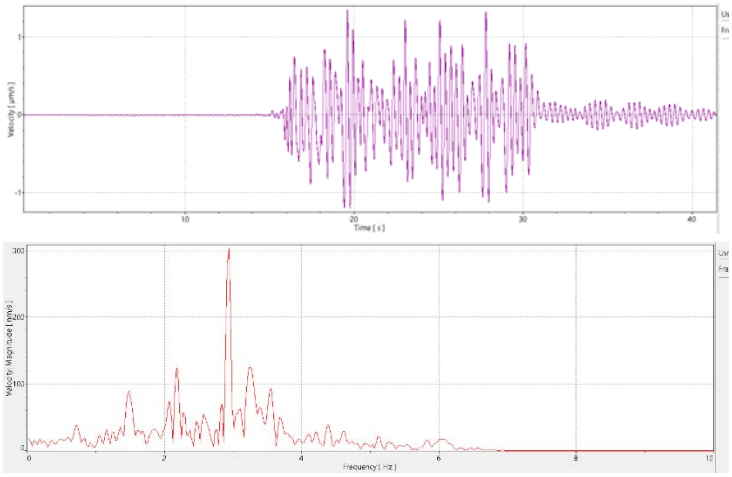

Figure 2 – Cos Cob Bridge: Velocity response in Time domain (up), Lateral FFT response, Frequency domain (down), Train 4, Metro-North M8 train with 8 cars at 12MPH.

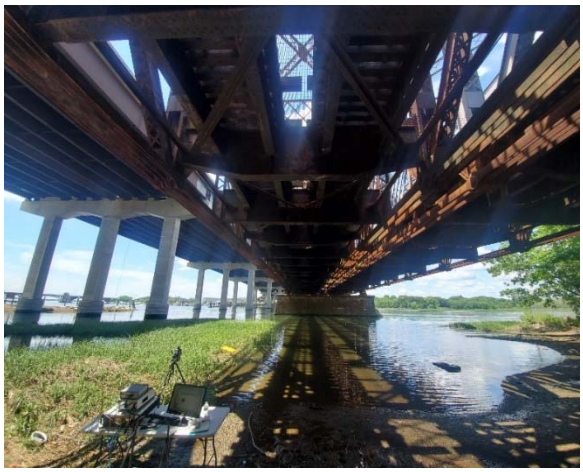

Figure 3 – Devon bridge: Working station under the bridge

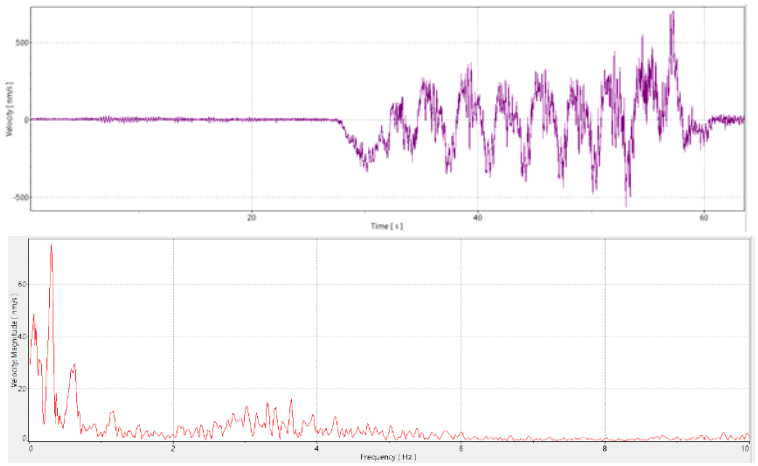

Figure 4 – Devon Bridge: Velocity response in Time domain (up), Lateral FFT response, Frequency domain (down)
Train 10, Metro-North M8 train with 8 cars at 13MPH.

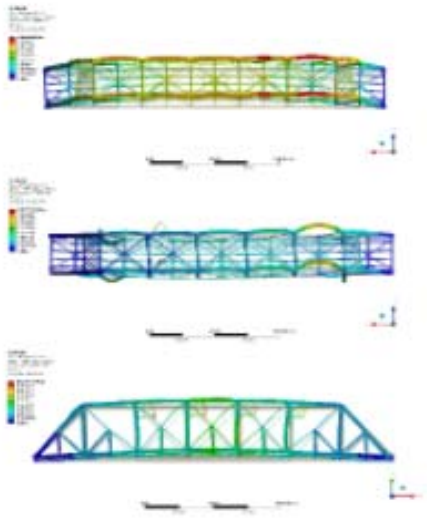

Figure 5: Devon bridge FEM mode-shape

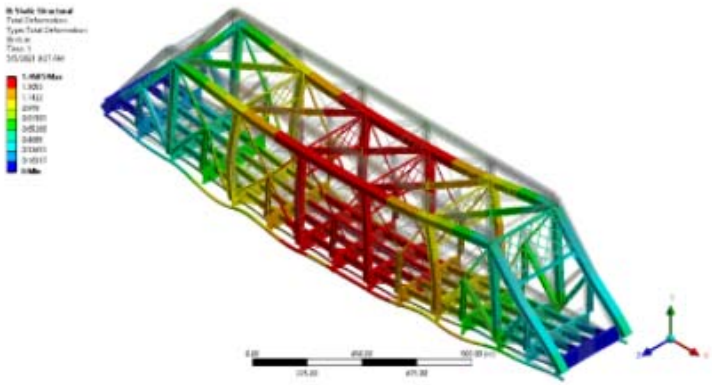

Figure 6: Devon bridge Devon bridge displacement under static Dead Load.

How these activities are helping achieve the overarching goal(s) of the project:

The primary goal of the project is to develop an efficient and cost-effective methodology for the structural health/condition and structural monitoring of old railroad bridges in New England, highlighting the dynamic response due to experimental and numerical techniques of the structure under service.

- The displacement time domain response obtained from the One Point Laser Vibrometer Test is being used to calibrate and verify the accuracy of the FE model, and to determine the ideal number of sensors for field testing. The time domain response will be helpful to determine displacement, stresses, and strain of the bridges under service load.
- The use of conventional accelerometers, standalone accelerometers, and One Point Laser Vibrometer will allow the research team to determine the most cost effective method for future monitoring campaigns.
- The updated model will be used to simulate different loading conditions of the bridge, with emphasis in service loads

Accomplishment achieved under the project goals:

Following accomplishments have been achieved and would help toward meeting the project goal:

- The research team has successfully completed field testing using One Point Laser Vibrometer on both Devon and Cos Cob bridge.
- The time domain data collected using these devices has been successfully transformed into frequency domain (Figure 2, and 4). Doing so, the research team has been able to determine approximated natural frequencies of both the Devon and the Cos Cob bridge.
- Significant progress has been made in updating and validating the FEM of both Devon and the Cos Cob bridge (Figure 5, and 6). Once the FEM is completed, the natural frequencies and the mode shapes obtained from the field test will be compared with FE model using Model Assurance Criterion (MAC).
- The research team continue to get support from the ConnDOT, Metro-North RR, and Polytec Inc. during field testing.
- The expected results obtained from the tensile testing, fatigue testing, metallographic testing, fractography and hardness indentation test will be helpful in assessing the mechanical behavior of these more than 100 years old steel.
- The research team has disseminated research findings through conferences (posters and presentations) and journal publication, and more draft paper/abstract has been prepared.
- The collaboration between the academic and industry institutions has been maintained.

Table 1: Task Progress

Task Number	Start Date	End Date	% Complete (as of now)
Task 1: Literature search and review; communication with New England state DOTs for railroad bridge material collection and information/data	October 1, 2018	December 31, 2020	100%
Task 2: Existing railroad bridge material testing	January 1, 2019	August 31, 2021	60%
Task 3: Finite Element (FE) modeling of railroad bridge	June 1, 2019	December 31, 2021	85%
Task 4: Determine optimal number and locations of sensor for effective bridge condition monitoring	December 1, 2019	January 31, 2022	25%
Task 5: Determine from the analytical and FEM analysis effects of vehicle speed/type on bridge response and DMF	June 1, 2020	May 31, 2022	10%
Task 6: Prepare procedure to field test and data collection by applying a limited number of sensors to bridge, collect	October 1, 2020	May 31, 2022	40%

field data, update FE Model, and verify that sensors give sufficient info to determine condition of bridge			
Final Report preparation and submission	January 1, 2022	June 30, 2022	0%
Overall Project:	October 01, 2018	June 30, 2022	75%

Table 2: Budget Progress

Project Budget	Spend – Project to Date	% Project to Date*
To be provided separately		

Include the date the budget is current to.

Opportunities for training/professional development that have been provided:

The research team members have been continuously trained by the Polytec Inc. to use their testing devices and data processing software.

- Single point laser Vibrometers training: May 28, 2021 at Hudson, MA office;
- Data processing PSV software, training: June 17, 2021 a Virtual meeting.

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events

Title	Event	Type	Location	Date(s)
Field Testing and FE Modeling of Selected Truss Railroad Bridges in Connecticut (by Ramesh B. Malla, Ph.D., F. ASCE, F. EMI, M. CASE (Professor), Celso de Oliveira, Research Assistant (Ph.D. Student), and Santosh Dhakal, Research Assistant (M.S. Student)	TIDC Showcase Presentations 2021	Conference	Virtual	May 19, 2021
Monitoring and Dynamic Response of Two More than Century Old Truss Railroad Bridge (Ramesh B. Malla, Ph.D., F. ASCE, F. EMI, M. CASE (Professor), Celso de Oliveira, Research Assistant (Ph.D. Student), and Santosh Dhakal, Research Assistant (M.S. Student)	International Bridge Conference 2021 (June 7 -11, 2021)	Conference	Virtual	June 11, 2021

Table 4: Publications and Submitted Papers and Reports

Type	Title	Citation	Date	Status
N/A				

Participants and Collaborators:

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members			
Individual Name	**Email Address**	**Department**	**Role in Research**
Dr. Ramesh B. Malla, Professor	Ramesh.Malla@UCONN.EDU	Department of Civil & Environmental Engineering, University of Connecticut, Storrs	Principal Investigator (PI)/ TIDC Institutional Lead, UConn
Dr. Lesley D. Frame, Assistant Professor	Lesley.Frame@UCONN.EDU	Department of Materials Science & Engineering, University of Connecticut, Storrs	Collaborator: Material characterization of the test specimens

Use the table below to list all students who have participated in the project during the reporting. (This includes all paid, unpaid, intern, independent study, or any other student that participated in this project.)

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
Celso de Oliveira			Civil Eng.	Graduate Assistant
Santosh Dhakal		M.S.	Civil Eng.	Graduate Assistant
Kelly Voong		Undergraduate		Student
Hernan Cortez				Student
Andrew Schroder				Student
Supporting Role				
Donghyun Kim		Ph.D	Material Science	Graduate Student
Sachin Tripathi		Ph.D.	Civil Eng.	Graduate Assistant
David Jacobs		Ph.D.	Civil Eng.	Graduate Student
Suvash Dhakal		Ph.D.	Civil Eng.	Graduate Student

Use the table below to list organizations have been involved as partners on this project and their contribution to the project.

Table 8: Research Project Collaborators during the reporting period						
Organization	**Location**	**Contribution to the Project**				
		Financial Support	**In-Kind Support**	**Facilities**	**Collaborative Research**	**Personnel Exchanges**
Conn DOT Contact persons: (1) Haresh Dholakia- Transportation Engineering Supervisor *(Technical Champion)*	Newington, CT		X	X	X	X

(2) Mr. Manesh Dodia- Transportation Engineer III *(Technical Champion)*						
Maine DOT Contact Persons: (1) Dale Peabody- TIDC Advisory Board, Director Transportation Research (2) Brian Reeves- Director of Rail Transportation	Augusta, ME		X	X	X	X
Metro-North Railroad Co. Contact persons: (1) Warren Best-Assistant Deputy Director- Structures *(Technical Champion)* (2) Ms. Hong McConnell, Senior Structural Engineer	Bridgeport, CT		X	X	X	X
Polytec, Inc., Hudson, MA Contact Person: Mr. Mario Pineda, Territory Manager	Hudson, MA		X	X	X	X

Table 9: Other Collaborators

Collaborator Name and Title	Contact Information	Organization and Department	Contribution to Research
Haresh Dholakia, Transportation Engineering Supervisor	HareshKumar.Dholakia@CT.GOV	Connecticut Department of Transportation (Conn DOT), Newington, CT	Technical Champion
Manesh Dodia, Transportation Engineer III	Manesh.Dodia@CT.GOV	Connecticut Department of Transportation (Conn DOT), Newington, CT	Technical Champion
Warren Best, Assistant Deputy Director-Structures	Best@MNR.ORG	Metro-North Railroad Company, Bridgeport, CT	Technical Champion
Hong McConnell, Senior Structural Engineer	McConnell@MNR.ORG	Metro-North Railroad Company, Bridgeport, CT	Coordinator for logistics for field test on bridges
Mario Pineda, Territory Manager	M.Pineda@POLYTEC.COM	Polytec Inc., Hudson, MA	Providing part of the field test Equipment (Laser Vibrometer) and advice conducting field test
Arend Von der Lieth, Application Engineering Manager	A.Vonderlieth@POLYTEC.COM	Polytec Inc., Hudson, MA	Providing art of the field test Equipment (Laser Vibrometer) and advice conducting field test
David Damiani, Application Engineering	D.Damiani@ POLYTEC.COM	Polytec Inc., Hudson, MA	Providing part of the field test Equipment

			(Laser Vibrometer) and advice conducting field test

Technical Champion for this project:
Name: Mr. Haresh Dholakia, P.E.
Title: Transportation Engineering Supervisor, Rail Design`
Organization: Connecticut Department of Transportation
Location (City & State): Newington, CT
Email Address: HareshKumar.Dholakia@CT.GOV

Name: Mr. Manesh Dodia
Title: Supervising Rail Officer, Rail Construction
Organization: Office of Rail – Constructions, Connecticut Department of Transportation
Location (City & State): New Haven, CT
Email Address: Manesh.Dodia@CT.GOV

Name: Warren Best, P.E.
Title: Assistant Deputy Director- Structures
Organization: Metro-North Railroad Company
Location (City & State): Bridgeport, CT
Email Address: Best@MNR.ORG

Challenges and Changes:
Actual and anticipated problems or delays and actions or plans to resolve them:

- The research team faced difficulty in setting up working station under the bridge (Figure 3) because of the water level and the tidal response. Because of this, the research team is unable to record data from some of the nodes directly above water.
- The equipment evaluation such as one point laser vibrometer, data acquisition system and other relevant related to the field test measurements have continued proven to be time and resources consuming.

Planned Activities:

- The research team will continue to perform in-depth processing of the data collected from both the Cos Cob and the Devon bridges field tests performed on June 6 & 7, 2021 and June 8, 2021, respectively.
- The research team will continue to work on material characterization. Significant progress is expected to be made on tensile testing, metallography, fractography and hardness indentation test by next reporting period.
- The research team will continue to calibrate the FE model of the Devon bridge with the result obtained from the files testing and continue working on the FE model of the Cos Cob bridge. Once the FEM is completed, the natural frequencies and the mode shapes obtained from the field test will be compared with FE model using Model Assurance Criterion (MAC).
- The research team will continue to work on finding more industrial collaborators who can support research directly with the testing equipment and logistics in the coming days.
- The research team will continue to work with Conn DOT, Metro-North RR, and Polytec Inc., preparing for the future Controlled field test on earlier fall on Cos Cob bridge.
- The research team will continue to maintain communication with CT and other New England DOTs, Metro-North Railroad company, and Polytec, Inc., so that the research will be relevant and of value to the DOTs and industry.