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: October 01, 2020 to December 31, 2020
Submission Date: December 30, 2020

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 Devon railroad bridge located over the Housatonic River between Milford and Stratford, CT. The data collected using the Laser Vibrometers and Accelerometers will be employed to update the Finite Element (FE) model of the bridge structure and validate the testing procedure. Also, a significant amount of time was spent on processing and analyzing the raw data from field tests, and preparation for the future test on Cos Cob bridge located over the Mianus River between Cos Cob and Riverside, CT. 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 the Devon bridge was performed on October 28, 2020 (Figure 1). For this test, the research team used a long stroke shaker to excite the bridge and collect the dynamic response using a Laser Vibrometer and conventional Accelerometers. The Metro-North RR and Polytec Inc, have actively supported the research team with equipment and logistics during the testing.
- The collected data has been pre-processed and compared to validate the previous dynamic study of the Devon bridge. The frequency response has proven to be within expected values, an in-depth processing is ongoing to validate the collected data (Figure 2).
- Efforts are ongoing to update FE model of the Devon bridge to understand the dynamic behavior of the structure.
- Preparation and logistics for Cos Cob bridge are ongoing, the research team expects to perform the preliminary test during this winter. The team has visited the bridge site with Mr. Warren Best from Metro-North RR on October 21, 2020, to identify the site conditions and prepare the logistics (Figure 3).
- The research team has spent a considerable amount of time exploring different equipment available in the market for structure monitoring campaigns. The University of Rhode Island has borrowed the standalone accelerometers that can be used on future field tests. The team is performing a controlled laboratory test in the time and frequency domain to validate the sensibility from those advantageous accelerometers (Figure 4).
- Close collaboration with Conn DOT, Metro-North RR, and Polytec Inc. has been maintained. The Metro-North RR has directly helped the research team with the bridge access and equipment logistics during the field test. The Conn DOT has been directly assisting the research team with required logistics and flag-man cost. Polytec, Inc. has been helping the team with part of the instrumentation and bridge shaker.
- The research Team has submitted the abstract and presented at 33rd Rhode Island Transportation Forum Virtual Edition the paper “Stress-Strain Behavior of Steel Material from Two Old Railroad Bridges” on October 30, 2020.
- The Team has been preparing a poster and video to be presented at Transportation Research Board 2021 Virtual conference with the paper “Tensile Test and Stress-Strain Behavior of Steel Material from a More than a Century Old Railroad Bridge” on January 25-29, 2021.
- The research team has received from Maine DOT under Mr. Dale Peabody Contact, steel plate material of a Railroad bridge located over the Arrostook River.

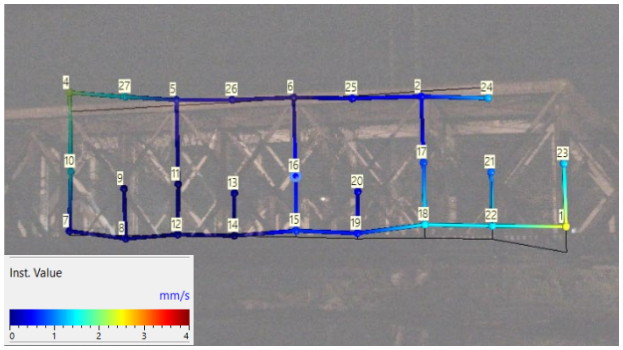

Figure 1 – Devon bridge: Vertical RMS Velocity at 4.8Hz

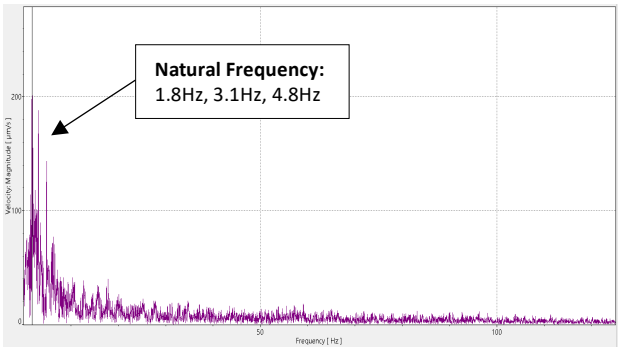

Figure 2 – Devon bridge: FFT Under Service Load (Train)


Figure 3 – Cos Cob bridge: Span 7 for Future Field Test

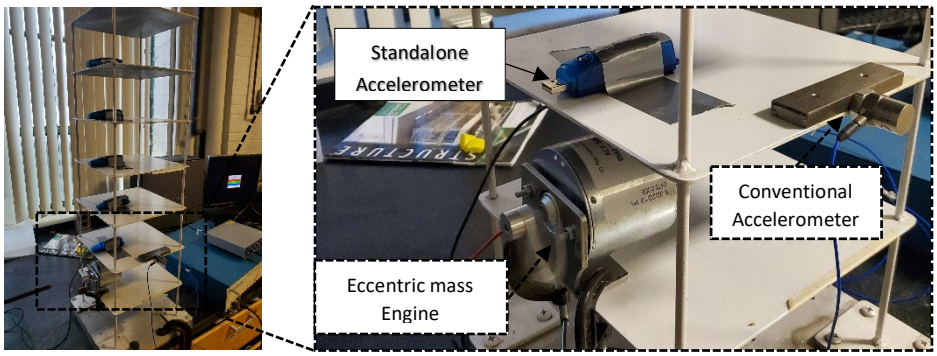

Figure 4 – Standalone Accelerometers Sensibility Validation

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 frequency domain response from field test will be used to calibrate the FE model, and to determine the ideal number of sensors for field testing. The time domain response will be help determine displacement, stresses and strain of the bridges under service load.
- The use of Laser Vibrometers versus Accelerometers will allow the research team to determine the most cost-effective method for future monitoring campaigns.
- The field tests will allow the research team to update the numerical model. The updated model will be used to simulate different loading conditions of the bridge.
- The testing of material from different Railroad bridges more than 100 years old will allow the team to have an insight into the mechanical behavior and chemical characteristics of those bridges material.

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

- Different methods of structure monitoring have been used for the field test. Based on the results, the team will adopt the most efficient and cost effective for future monitoring campaigns.
- The FFT has identified different natural frequencies and mode shapes within the field data from the Devon bridge. The natural frequencies and mode shapes will be compared with the FE model, using the Modal Assurance Criterion (MAC) and other statistical methods. The FE model will be calibrated to reflect the realistic structure response.
- Cooperation with universities has been maintained. The University of Rhode Island has borrowed standalone Accelerometers to be used in future field tests, if the equipment proves to be reliable.
- Partnership with state DOT's and industry companies have been maintained. The ConnDOT, Metro-North RR, and Polytec Inc. provided vital support for the planned field test.
- The research team has disseminated research findings through conferences (posters and presentations) and journal publication, and also more draft paper/abstract has been prepared.

Table 1: Task Progress

Task Number	Start Date	End Date	% Complete
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	September 30, 2020	55%[1]
Task 3: Finite Element (FE) modeling of railroad bridge	June 1, 2019	December 31, 2020	72%
Task 4: Determine optimal number and locations of sensor for effective bridge condition monitoring	December 1, 2019	January 31, 2021	25%
Task 5: Determine from the analytical and FEM analysis effects of vehicle speed/type on bridge response and DMF	June 1, 2020	August 31, 2021	5%
Task 6: Prepare procedure to field test and data collection by applying a limited number of sensors to bridge, collect field data, update FE Model, and verify that sensors give sufficient info to determine condition of bridge	October 1, 2020	September 31, 2021	20%[1]
Final Report preparation and submission	June 1, 2021	September 31, 2021	0%
Overall Project:	October 01, 2018	September 31, 2021	65%

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:
N/A

1. Activity in delay due to COVID-19 (Coronavirus Pandemic)

Activities involving the dissemination of research results:

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

Title	Event	Type	Location	Date(s)
Devon Railroad Bridge (CT) – Field Test Preparation	Meeting with Mr. Mario Pineda and Mr. Arend von der Lieth, from the Polytec Inc, Hudson, MA	Meeting	Virtual	October 2, 5, 8, 9 23, 28, 2020
Cos Cob Railroad Bridge (CT) – Guided Site Visit	Meeting with Mr. Best from Metro-North RR	Site Visit	Cos Cob Bridge	October 21, 2020
Stress-Strain Behavior of Steel Material from Two Old Railroad Bridges	33rd Rhode Island Transportation Forum Virtual Edition	Conference	Virtual	October 30, 2020
Devon Railroad Bridge (CT) – Field Test Results Discussion	Meeting with Mr. Mario Pineda and Mr. Arend von der Lieth, from the Polytec Inc, Hudson, MA	Meeting	Virtual	November 24, 30, December 7, 18, 2020

Table 4: Publications and Submitted Papers and Reports

Type	Title	Citation	Date	Status
Conference Presentation	Stress-Strain Behavior of Steel Material from Two Old Railroad Bridges	By Celso de Oliveira, Sachin Tripathi, Mark Castaldi, and Ramesh Malla *33rd Rhode Island Transportation Forum*	October 30, 2020	Presented
Conference Presentation	Tensile Test and Stress-Strain Behavior of Steel Material from a More than Century Old Railroad Bridge	By Celso de Oliveira, Sachin Tripathi, Mark Castaldi, and Ramesh Malla *2021 TRB Annual Meeting*	January 25-29, 2021	Accepted for presentation
Conference Presentation	Monitoring and Dynamic Response of Two More than Century Old Truss Railroad Bridges	By Celso de Oliveira, Sachin Tripathi, and Ramesh Malla *2021 International Bridge Conference*	June 7-10, 2021	Accepted for presentation

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		Department of Materials Science & Engineering, University of Connecticut, Storrs	Material characterization of the test specimens

Table 6: Student Participants during the reporting period

Student Name	Email Address	Class	Major	Role in research
Celso de Oliveira		Ph.D.	Civil Eng.	Graduate Assistant
Sachin Tripathi		Ph.D.	Civil Eng.	Graduate Assistant
David Jacobs		Ph.D.	Civil Eng.	Graduate Student
Suvash Dhakal		Ph.D.	Civil Eng.	Graduate Student

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*) (2) Mr. Manesh Dodia- Transportation Engineer III (*Technical Champion*)	Newington, CT		X	X	X	X
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

Table 9: Other Collaborators			
Collaborator Name and Title	**Contact Information**	**Organization and Department**	**Contribution to Research**
Haresh Dholakia, Transportation Engineering Supervisor		Connecticut Department of Transportation (Conn DOT), Newington, CT	Technical Champion
Manesh Dodia, Transportation Engineer III		Connecticut Department of Transportation (Conn DOT), Newington, CT	Technical Champion
Mr. Warren Best, Assistant Deputy Director- Structures		Metro-North Railroad Company, Bridgeport, CT	Technical Champion
Mario Pineda, Territory Manager		Polytec Inc., Hudson, MA	Part of the field test Equipment (Laser

			Vibrometer and Shaker) and help conducting field test
Arend Von der Lieth, Application Engineering Manager		Polytec Inc., Hudson, MA	Part of the field test Equipment (Laser Vibrometer and Shaker) and help conducting field test

Technical Champion for this project:
Name: Haresh Dholakia
Title: Transportation Engineering Supervisor
Organization: Connecticut Department of Transportation
Location (City & State): Newington, CT

Name: Manesh Dodia
Title: Transportation Engineer III
Organization: Connecticut Department of Transportation
Location (City & State): Newington, CT

Name: Warren Best
Title: Assistant Deputy Director- Structures
Organization: Metro-North Railroad Company
Location (City & State): Bridgeport, CT

Changes:
Actual and anticipated problems or delays and actions or plans to resolve them:
Since the last Quarterly report, there were few changes regarding the University policy of using the Laboratory due to COVID-19. Also, Aroostook river bridge material, a limited material collected on Cos Cob, Devon, and Atlantic Street bridges still left, and tensile coupons are ready to be tested. The team has been maintaining close contact with the laboratory personnel to proceed with material characterization tests.
The research team has had to reschedule the Devon field in two different occasions, due to the COVID-19 traveling policy and weather condition.
The equipment evaluation such as accelerometers, data acquisition system and other relevant related to the field test measurements has proven to be time and resources consuming.

Planned Activities:
- The Research team will process in-depth the output data from the Devon bridge field test. The accurate finite numerical model is almost under completion.
- The preliminary FE model of Cos Cob will continue to be developed and will be used on the sensor planning for the planned field test.
- The research team is preparing the logistics with Conn DOT and Metro-North RR for a preliminary data collection during the winter on Cos Cob bride, using the standalone accelerometers.
- 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 spring 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.