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, 2020 to June 30, 2020
Submission Date: July 01, 2020

Overview:
Brief overview and summary of activities performed during the reporting period:
Activities performed during this reporting period have been focused primarily on analyzing the results from the tested material that was collected from historic railroad bridges in New England, Finite Element (FE) modeling a bridge of interest to Connecticut Department Of Transportation (Conn DOT), and preparing methodologies for the field testing and data collection during service conditions on the selected railroad bridges.

- Materials from stringers and angles, from Devon (Stratford, CT), and Cos Cob (Greenwich, CT) bridges respectively have been tested and the results analyzed in detail.
- Efforts is ongoing to create an accurate FE model of Cos Cob and Devon bridge, by using the tensile test results and filed data collected in 2015 (in case of Devon bridge, Malla et al 2017) and to update the model.
- Preliminary work procedure and budget for the planned field testing and data collection of Cos Cob and Devon bridges under service loading condition has been prepared and will be presented to interested parties.
- Collaboration with Conn DOT and Metro-North Railroad (MNRR) company has been maintained. The meeting with Conn DOT technical champions Mr. Haresh Dholakia, Mr. Manesh Dodia and Mr. Warren Best toke place on June 30/July 01, 2020

How these activities are helping achieve the overarching goal(s) of the project:
The overarching goal of the project is to determine the structural health/condition and structural monitoring of old railroad bridges in the northeast corridor. Based on limited number on specimens, tensile testing results has shown that the material has maintained similar material properties that it had when put into service over 100 years ago. Tensile testing results has revealed a consistent yielding region between the yield strain point from the elastic region to plastic deformation and the yield strain point from the plastic deformation region to work hardening. . The results from the tensile test allow us to validate the collected material in ASTM A7 specification (see Table A) and calibrate the FE model, this model of the Cos Cob and Devon bridge will allow simulations of the moving train loads to assess the effect of higher speed trains and the local fatigue in critical members.

Preliminary work procedure document was produced during the same period, this document contains relevant information related to work methodologies and safety requirements during the field testing and data collection of the selected bridges. This document will be shared with Connecticut Department of Transportation (Conn DOT) and Metro-North Railroad company (MNRR), and includes in detail project objectives, bridge details, equipment selection, safety requirements and other relevant information. Previous research has suggested genetic algorithm (GA) to be more effective to implement on large structures such as bridges for sensor optimization. However, there are limited published articles. Successful implementation of sensor optimization and validation from the experimental test bridge will help to develop the methodology which should be translatable to other railroad bridges as well.

Accomplishments achieved under the project goals:

- Sample material collected from Cos Cob and Devon railroad bridge members have been tested, analyzed and compared;
    - Material has maintained its Young's modulus of elasticity, yield strength, the specific yield strain points at the beginning and end of yielding where strain-controlled hysteresis loading are expected to be performed during hysteresis analysis. Similarly, monotonic failure curves have been studied to determine strain energy to create failure and ultimate tensile strength.

  - Based on a limited number of specimens, Cos Cob bridge material showed lower ultimate tensile strength than ASTM A7 steel specifications. (see Figure 1). However, it should be added that the material collected from the bracket used in the footbridge along the side of the main RR bridge.
  - For Devon Bridge, Four out of the five test coupons showed relatively similar ultimate tensile strength in comparison with ASTM A7 steel specifications (see Figure 2).
- Fatigue coupons have been cut and are ready to be tested and create more conclusions. Detailed FE model of the Devon Bridge (see Figure 3) is near completion.
- The research team has been conducting literature review on best practices for field data collection and the best methodologies available in the market.
- Equipment manufacturers have been contacted for the budged estimation and possible sponsorship.
- The preliminary work procedure has been prepared and will be shared with the concerned parts.

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	95%
Task 2: Existing railroad bridge material testing	January 1, 2019	September 30, 2020	50%[1]
Task 3: Finite Element (FE) modeling of railroad bridge	June 1, 2019	December 31, 2020	60%
Task 4: Determine optimal number and locations of sensor for effective bridge condition monitoring	December 1, 2019	January 31, 2021	15%
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	0%
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	10%*
Final Report preparation and submission	June 1, 2021	September 31, 2021	0%
Overall Project:	October 01, 2018	September 31, 2021	50%

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 has completed the online training regarding the safety precautions at the lab due to COVID-19 - "Returning to Research: COVID-19 Training for UConn and UConn Health Researchers."
During this quarterly period one of the research team member, Mark Castaldi, has graduated with M.S. in Mechanical Engineering. Mark's research has contributed to material analysis and validation under ASTM specifications.

*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)**
"Material Tensile Testing and Analysis of Very Old Steel Railroad Bridges for Health Assessment" (Master's degree research project report)	M.S. Thesis defense by Mark Castaldi	Oral Presentation	University of Connecticut, Department of Civil & Environmental Engineering (Virtual)	May 08, 2020
Discussion about possible use of vibrometers and accelerometers for field data collection	Meeting with Mr. Mario Pineda, Director of Customer Relations, Polytec - Boston	Meeting	Virtual	May 15th, 2020
TIDC Project 1.2: Condition/Health Monitoring of Railroad Bridges for Structural Safety, Integrity, and Durability	Meeting with Technical Champions for the project, Manesh Dodia and Haresh Dholakia from Conn DOT Rail Division, and Warren Best from MNRR company.	Meeting	Virtual	June 30th / July 1st, 2020

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
Conference Presentation	Material properties and remaining life estimation of old railroad steel bridges	2020 TIDC Annual Conference	30th June, 2020	Abstract submitted
M.S. research project report	Material Tensile Testing and Analysis of Very Old Steel Railroad Bridges for Health Assessment	University of Connecticut	8th May, 2020	Report submitted

Figures:

Figures 1 and 2 provide the stress-strain curve of Cos Cob and Devon bridges respectively. Points 1, 2, and 3 (red dotted circles) from plots are described in Table A and are taken from ASTM A7 (ASTM A7-1939) standard.

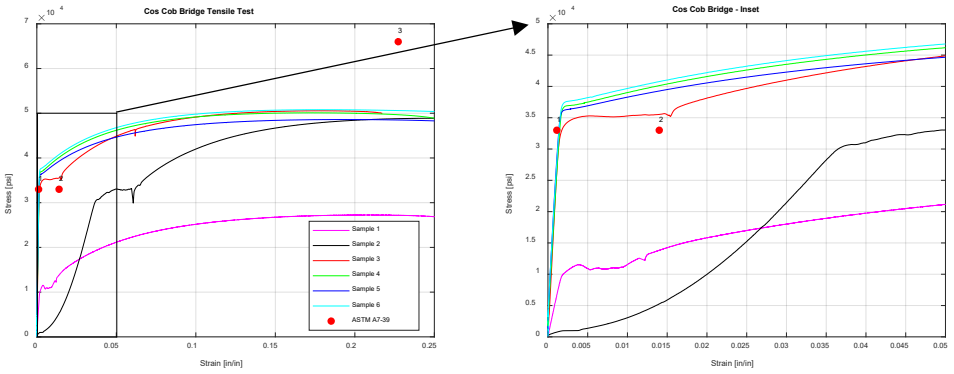

Figure 1 - Cos Cob bridge Stress-Strain plot

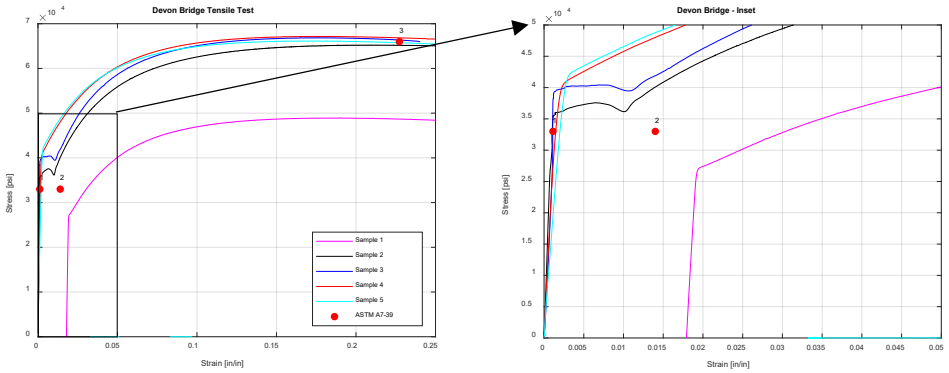

Figure 2 - Devon bridge Stress-Strain plot

Table A - ASTM A7 steel mechanical properties (ASTM A7-1939)

Point #	Strain (in/in)	Stress (psi)	Description
1	0.00112	33,000	Yield point
2	0.01400	33,000	Yield Point Elongation
3	0.22727	66,000	Ultimate point

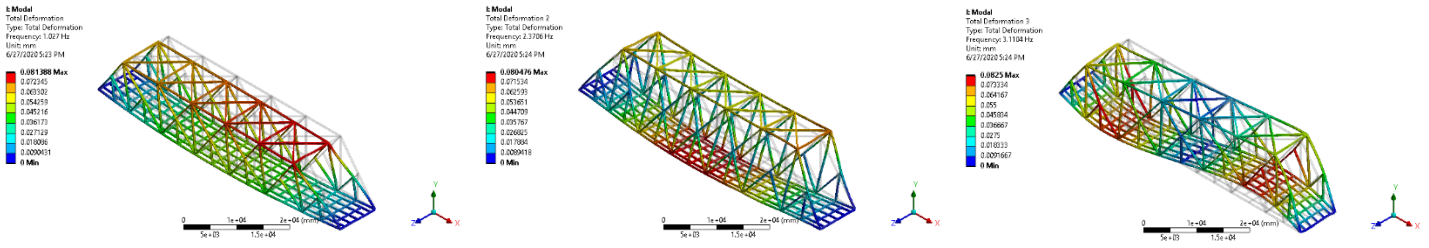

Figure 3 – Initial FE model of Devon bridge, mode shapes

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	Civil & Environmental Engineering, University of Connecticut, Storrs	Principal Investigator (PI)/ TIDC Institutional Lead, UConn
Dr. Nicholas Eddy		Institute of Material Science, University of Connecticut, Storrs	Mechanical Testing Lab
Dr. Fiona Leek		Department of Materials Science & Engineering, University of Connecticut, Storrs	Material Analysis Lab
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
Mark Castaldi		M.S.	Mech. Eng.	Graduate Assistant
David Jacobs		Ph.D.	Civil Eng.	Graduate Student
Suvash Dhakal		Ph.D.	Civil Eng.	Graduate Student

Table 7: Student Graduates			
Student Name	**Role in Research**	**Degree**	**Graduation Date**
Mark Castaldi	Material analysis and classification	Master of Science	May 21, 2020

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**
		Mark the appropriate contribution with an "x"				
Conn DOT Contact persons: (1) Haresh Dholakia-Transportation Engineering Supervisor (*Technical Champion*) (2) Mr. Manesh Dodia-Transportation Engineer III (*Technical Champion*) (3) Andrew Mroczkowski-TIDC Advisory Board, Transportation Engineer III (4) Mr. Edgardo Block-Manager, Research unit (5)John Bernick-Assistant Rail Administrator	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
Mass DOT Contact Persons: (1) Brian Clang-TIDC Advisory Board, State Bridge Inspection Engineer	Taunton, MA					X

(2) Jim Sousa-Assistant Resident Engineer						
Metro-North Railroad Co. Contact persons: (1) Warren Best-Assistant Deputy Director- Structures (*Technical Champion*) (2) Nick Watert- Engineering Supervisor- Structures	Bridgeport, CT		X	X	X	X
RI DOT Contact Persons: (1) Dr. Kate Wilson- TIDC Advisory Board, Principal Engineer (2) Donald Murphy-Senior Civil Engineer	Providence, RI					X
Vermont DOT Contact person: Dr. Emily Parkany- TIDC Advisory Board, Research Manager	Barre, VT					X
NH DOT Contact Person: (1) Robert Landry-TIDC Advisory Board, Bridge Design Administrator (2) John Robinson- Railroad Safety Inspector/Investigator	Concord, NH					X
Polytec, Inc. Contact Person: Mr. Mario Pineda, Territory Manager	Hudson, MA		X			X

Table 9: Other Collaborators

Collaborator Name and Title	Contact Information	Organization and Department	Contribution to Research
			(i.e. Technical Champion)
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.	Potential Field Test Equipment

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:

Limited material collected on Cos Cob, Devon and Atlantic Street bridges still left, and fatigue coupons are ready to be tested. The team was not able to do material testing since February 2020 due to the University shut down because of the COVID-19 (Coronavirus) pandemic. The labs have been partially opened with precautionary measures since June 20, 2020 and the team are communicating with laboratory technical personnel on restarting the material testing. Once the team are given green signal, the material testing will be resumed.

Planned Activities:

- As mentioned above, due to Coronavirus outbreak, the University of Connecticut is partially closed and faculty, staff and students are teleworking. Currently, all members of the research teams are working remotely online on tasks that are based on analytical and computational in nature.
- The accurate finite element (FE) model of Cos Cob and Devon bridges will continue to be developed and calibrated. The moving train load simulation with different speeds will be applied on each model.
- The research team will continue to work with Conn DOT and MNRR through the logistics of scheduling-controlled field testing to test its sensor placement and data collection methodologies.
- The research team will continue to maintain communication with DOTs regarding potential future research topics so that the research will be relevant and of great importance to the DOTs and industry.

References:

ASTM (1939). *Standard Specifications for Steel for Bridges and Buildings, A7-39.* American Society of Testing & Materials, West Conshohocken. 1939.

Malla, R. B., Jacobs, D., Dhakal, S., and Baniya, S. (2017). "Dynamic Impact Factors on Existing Long-span Railroad Bridges," Rail Safety *Project – 25 Final Report,* Transportation Research Board, Washington D.C., February, 40 pages. (Online - http://onlinepubs.trb.org/onlinepubs/IDEA/FinalReports/Safety/Safety25.pdf)