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: January 01, 2020 to March 31, 2020
Submission Date: March 31, 2020

Overview:

Brief overview and summary of activities performed during the reporting period:
Activities performed during this reporting period have been focused on preparing test coupons for material testing, performing testing, logging and analyzing information about the historic railroad bridges in New England, Finite Element modeling a bridge of interest to ConnDOT, and preparing methodologies and logistics of planned field testing activities on active railroad bridges.

- Material representing floor beams, girders, stringers, string angles, and bracing members from the Atlantic Street (Stamford, CT), Devon (Stratford, CT), and Cos Cob (Greenwich, CT) Bridges has been lead paint abated as preparation for cutting coupons for safe material testing.
- About 40 test coupons have been prepared from the aforementioned bridge material for tensile, hysteresis, and fatigue testing.
- Tensile testing has been performed on the Cos Cob and Devon material.
- Efforts are being continued to create an accurate FE model of Cos Cob bridge.
- Information gathering on various methodologies, including genetic algorithm, to determine optimum number and location for sensor placement and data collection and processing have been researched.
- Logistics preparation for the railroad bridge field tests and data collection planned for upcoming summer has begun.
- Collaboration with Conn DOT has been maintained and a meeting with Conn DOT technical champions took place on Friday March 20, 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 of old railroad bridges in the northeast corridor. Tensile testing has shown that this material has maintained similar material properties that it had when put into service over 100 years ago. Tensile testing 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. Strain controlled hysteresis loading will be performed in this strain range from which the team expects to be able to develop total strain life curves and a strain energy analysis comparing the strain energy dissipated in one cycle at some stress/strain level and the number of cycles to failure at that stress/strain level based on the strain energy required for monotonic failure. For the material tested- for Cos Cob the surface was unchanged and for Devon 0.025” was removed from each side to achieve flatness so the team is confident that these specimens represent the members that were in service. Fatigue testing will be a third component in the effort to assess remaining life of this material.

FE modeling of the Cos Cob Bridge will allow simulations of the moving train loads to assess the effect of higher speed trains. Material testing of the Cos Cob Bridge can be factored into the model and fatigue life simulations can be performed with the FE model. ConnDOT expressed a desire to evaluate the Cos Cob Bridge and Devon Bridge through field testing. Being able to compare field test results to the FE model to further calibrate the model will result in even more accurate simulations.

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. The work on the logistics and preparation of the field test will help contribute toward successful field test of railroad bridges which is an integral part of this project.

Accomplishments achieved under the project goals:

- Material behavior of the Cos Cob and Devon railroad bridge members have been evaluated and compared
  - Material has maintained its Youngs modulus, its yield strength, the specific yield strain points at the beginning and end of yielding where strain controlled hysteresis loading will be performed has been determined, monotonic failure curves have been studied to determine strain energy to create failure and ultimate tensile strength.
  - Devon railroad bridge stringer angle material showed high ultimate tensile strength and higher amount of strain energy required to create monotonic failure suggesting that its remaining life is greater than Cob's.
- More material has been collected and coupons have been cut and are ready to test to create more conclusions, specifically hysteresis and fatigue tests.
- An complete FE model of the Cos Cob Bridge is near completion.
- The research team has been conducting literature review on the optimum number of locations and number of sensors to determine the overall bridge response during this reporting period. The team is exploring methodologies such as Genetic Algorithm to approach for this task.
- The research team has begun preparation for the railroad bridge field test and data collection during the summer. The preparation includes work procedure, equipment selection and calibration, safety requirements and insurances.
- Collaboration with ConnDOT has been maintained and a constructive discussion and feedback from the Conn Dot Technical Champions, Messrs. Hareshkumar Dholakia and Manesh Dodia were received at the meeting held on Friday March 20, 2020

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	10/01/2018	06/01/2020	95%
Task 2: Existing railroad bridge material testing	01/01/2019	09/30/2020	50%
Task 3: Finite Element (FE) modeling of railroad bridge	06/01/2019	12/31/2020	50%
Task 4: Determine optimal number and locations of sensor for effective bridge condition monitoring	12/01/2019	01/31/2021	10%
Task 5: Determine from the analytical and FEM analysis effects of vehicle speed/type on bridge response and DMF	06/01/2020	08/31/2021	0%
Task 6: Apply limited number of sensors to bridge, collect data, verify FEM, verify that sensors give sufficient info to determine condition of bridge	10/01/2020	09/31/2021	10%
Overall Project:	10/01/2018	09/31/2021	40%

Table 2: Budget Progress

Project Budget	Spend – Project to Date	% Project to Date*
$498,000	$143,441.62	28.8% (3/31/2020)

Include the date the budget is current to.

Opportunities for training/professional development that have been provided:

The research team has been trained to conduct fatigue and tensile tests on the Instron machine operated by Institute of Material Science (IMS), UConn. (A different machine than the 150 kN ADMET test set that had been used previously)

Activities involving the dissemination of research results:

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

Title	Event	Type	Location	Date(s)
Basic Civil/Structural Fundamentals of Movable Bridges	Structures and Applied Mechanics Seminar Series	Seminar – UConn By David Jacobs	University of Connecticut, Department of Civil &Environmental Engineering	02/28/2020
TIDC Project 1.2: Condition/Health Monitoring of Railroad Bridges for Structural Safety, Integrity, and Durability	Meeting with ConnDOT Rail Division Technical Champions for the project, Manesh Dodia and Haresh Dholakia	Meeting	Online	03/20/2020
TIDC Project 1.2: Condition/Health Monitoring of Railroad Bridges for Structural Safety, Integrity, and Durability	TIDC Quarterly Report Presentation	Meeting	Online	01/24/2020

The seminar conducted by David Jacobs, one of the Student Participants of this research, covered the basics of movable bridges, both highway and railroad. The current AASHTO and AREMA code requirements regarding movable bridges was discussed.

The meeting with Conn DOT engineers Messrs. Manesh Dodia and Haresh Dholakia, who are serving as the Technical Champion for this project was very constructive. The team presented on the research project giving background, research need, objectives, tasks and work accomplished to date. Discussion also took place on the selection of bridges for field testing. Conn DOT expressed interest in doing field testing on the Cos Cob Bridge in Greenwich, CT and the Devon Bridge in Stratford, CT.

Figures:

Figure 1: 150 kN ADMET Test Set

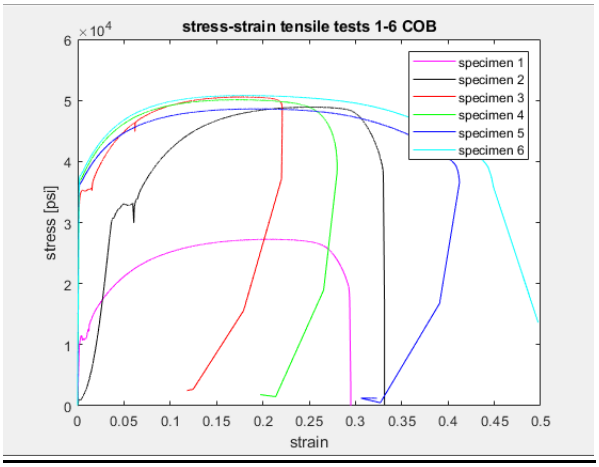

Figure 2: Monotonic Failure Cos Cob (note specimen 4-6 had yielded in prior tests which is why there is no plastic deformation region) (note 1-2 done w/o extensometer)

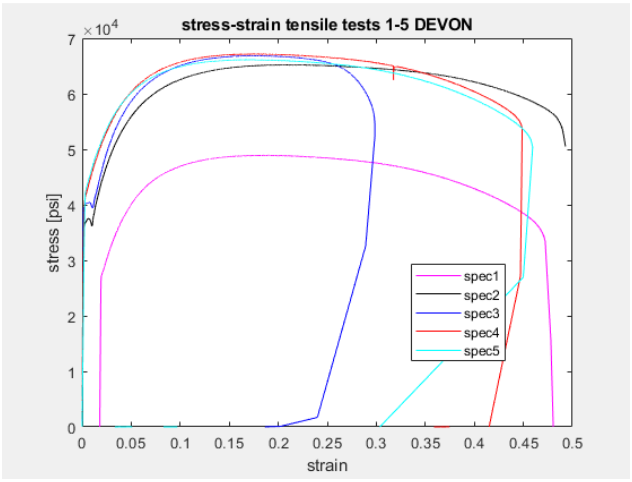

Figure 3: Monotonic Failure Devon Stringer Specimens

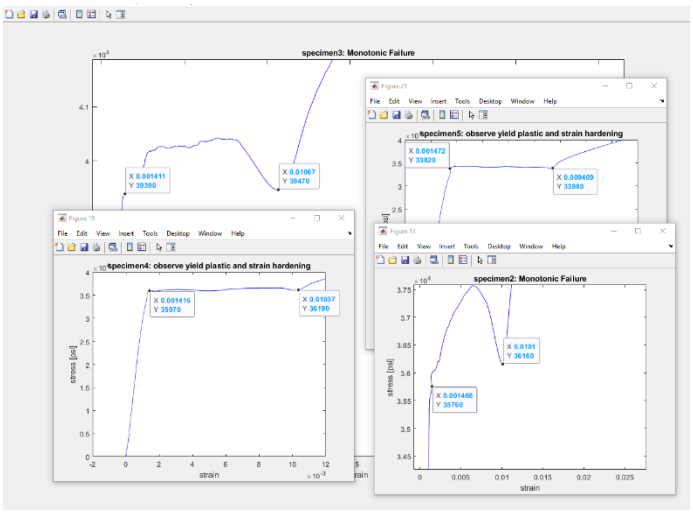

Figure4:Determination of yield points from linear to plastic deformation and from plastic deformation to work hardening

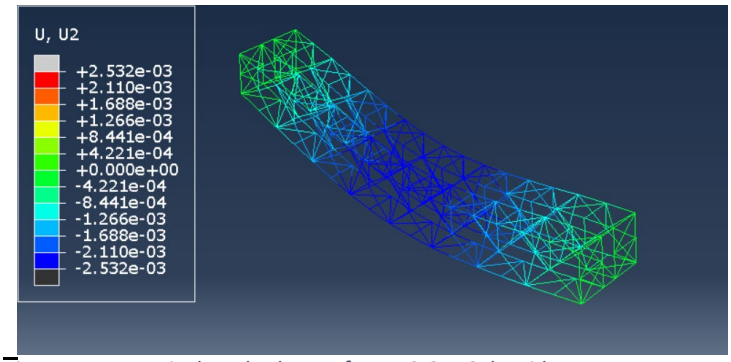

Figure 5: 1st vertical mode shape of span 3 Cos Cob Bridge

Participants and Collaborators:

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members			
Individual Name	**Email Address**	**Department**	**Role in Research**
Prof. Ramesh B. Malla	Ramesh.Malla@UCONN.EDU	Civil & Environmental Engineering, University of Connecticut, Storrs	Principal Investigator (PI)/ TIDC Institutional Lead, UConn
Andrew Mroczkowski		ConnDOT- Transportation Engineer III Newington, CT	TIDC Advisory Board/ CT DOT contact
Haresh Dholakia		Conn DOT- Transportation Engineering Supervisor Newington, CT	Technical Champion
Manesh Dodia		Conn DOT- Transportation Engineer III	Technical Champion
Edgardo Block		Conn DOT- Research Manager Newington, CT	CT DOT Research Contact
Mr. Warren Best		Assistant Deputy Director- Structures, Metro-North Railroad Company, Bridgeport, CT	Technical Champion from Metro-North RR company

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
Mark Castaldi		Masters	Mechanical Eng	Research Assistant
David Jacobs		PhD	Civil Eng	Graduate Student
Suvash Dhakal		PhD	Civil Eng	Graduate Student
Sachin Tripathi		PhD	Civil Eng	Graduate Assistant
Celso de Oliveira		PhD	Civil Eng	Graduate Assistant

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**
ConnDOT Contact persons: (1) Andrew Mroczkowski-TIDC Advisory Board, Transportation Engineer	Newington, CT		X	X	X	X

(2) Haresh Dholakia-Transportation Engineering Supervisor (3) Mr. Manesh Dodia-Transportation Engineer III (4) Mr. Edgardo Block-Manager, Research unit (5)John Bernick-Assistant Rail Administrator						
Maine DOT Contact Persons: (1) Dale Peabody- TIDC Advisory Board, Director Transportation Research (2) Brian Reeves- Director of Rail Transportation	Augusta, ME				X	X
Kleinfelder, Inc./Maine DOT Contact person: Lew Benner-Project Resident	Augusta, ME					X
MassDOT Contact Persons: (1) Brian Clang-TIDC Advisory Board, State Bridge Inspection Engineer (2) Jim Sousa-Assistant Resident Engineer	Taunton, MA					X
AAIS Contact person: Keith Godreau-Estimator	West Haven, CT			X		X
Metro-North Railroad Co. Contact persons: (1) Warren Best-Assistant Deputy Director- Structures (2) Nick Watert- Engineering Supervisor- Structures	Bridgeport, CT			X		X
RI DOT Contact Persons: (1) Dr. Kate Wilson- TIDC Advisory Board, Principal Engineer (2) Donald Murphy-Senior Civil Engineer						X
Vermont DOT Contact person: Dr. Emily Parkany- TIDC Advisory Board, Research Manager						X
NH DOT Contact Person:						X

(1) Robert Landry-TIDC Advisory Board, Bridge Design Administrator (2) John Robinson- Railroad Safety Inspector/Investigator						

Changes:

Actual and anticipated problems or delays and actions or plans to resolve them:
The research team's 7 months of diligent effort to get the Cos Cob, Devon, and Atlantic Street railroad bridge material lead paint abated (discussed in previous reports) has finally paid off. The bridge pieces have been now lead abated and cleaned utilizing the State of Connecticut approved vendor, AAIS at North Haven, CT.

The research team had several test coupons from the bridge materials prepared in February. The team was able to do some testing. However, due to busy schedule of the lab usage by many students and researchers during when the classes were in session, substantial testing in this project was scheduled during the Spring break, March 15 to 21, 2020. That could not be accomplished because the University labs have been shut down because of the Coronavirus pandemic (COVID-19). It is unclear when lab activities can resume. Lab manager does have a summer appointment and will be available all summer. If pandemic subsides team will be able to do a lot of testing including hysteresis and fatigue.

Due to the University and laboratory shutdown due to COVID-19 "Coronavirus outbreak" the university is working remotely. The research will focus on FEA modeling of the recommended bridges and preparation works for the field data collection.

Planned Activities:

- As mentioned above, due to Coronavirus outbreak, the University of Connecticut, as any other universities, is partially closed and faculty, staff and students are teleworking. It is hoped that the University will open soon and testing can resume. Currently, all members of the research teams are working remotely online on tasks that are based on analytical and computational in nature and do not need laboratory experiments.
- The finite element (FE) model of Cos Cob Bridge will be continued and completed and the moving train load simulation will be applied;
- The research team will continue to do further more literature reviews to determine the optimum number and locations of sensors to for the overall accurate bridge response. One of the appropriate optimization methodologies will be implemented on the bridge used for testing.
- The research team will continue the preparation of logistics and all necessary arrangement for the field tests and data collection anticipated during the summer. These tasks will include work procedure, equipment selection and calibration, safety requirements and insurances.
- The research team will continue to work with ConnDOT and Metro-North 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 and collaboration with various New England DOTs and industry regarding potential future research direction in the project so that the research will be relevant and of great importance to the DOTs and industry.