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, 2019 to December 31, 2019
Submission Date: January 01, 2020

Overview:

Overview and summary of activities performed during the reporting period:

A brief overview and summary of activities performed during the reporting period is presented below. Research work performed over this reporting period has been aligned with Tasks 1-3 of the proposal.
Per **task 1**, regular communication has been established and maintained with the DOT contacts from each of the 6 New England states. The purpose of this communication is to identify potential opportunities for obtaining railroad bridge steel samples that the research team will conduct material testing (task 2). The team has identified material from 3 different steel railroad bridges in Connecticut. Maine DOT has informed that they have material available for testing. The plan is for Maine DOT to ship this material to the UConn research team. Massachusetts DOT has identified a railroad bridge project involving the removal of steel that is to take place January-February of 2020.

Figure 2: Photograph of the Cos Cob Bridge, Greenwich, CT

Per **task 2**, efforts are being made to procure test coupons from 3 steel railroad bridges, Cos Cob, Atlantic Street, and Devon railroad bridges in Connecticut. The first step in this process is to remove all lead paint from the metal to ensure environmental and health safety during the cutting and testing of the coupons. The research team identified the CT State public health certified and UConn approved lead abatement vendor AAIS in West Haven, CT to perform the lead paint abatement. The material was delivered to their facility on December 12, 2020. The team has established a series of planned tests for this material to study their fatigue and tensile properties and how they compare to the original material properties and how the actual accumulated fatigue compares to that calculated using AREMA equations.
Per **task 3**, the team has begun creating a Finite Element (FE) model representative of a series of spans of the Cos Cob railroad bridge, Greenwich, CT. The Cos Cob bridge was built in 1904. Pictures of the current Cos Cob Bridge are shown in Figure 1 and Figure 2. Connecticut DOT was kind enough to share many sets of drawings of the Cos Cob Bridge including the original 1904 drawings and repair drawings from 1989 created by A.G. Lichtenstein Construction Company as part of a major repair effort. A plan and elevation drawing of all spans of the bridge are shown in Figure 3. The total bridge length is approximately 1087 feet and has 11 spans. The team will be modeling spans 3-6 which are each about 125 feet long. An example of a helpful drawing used when creating the model from the original 1904 set of drawings is shown in Figure 4. The

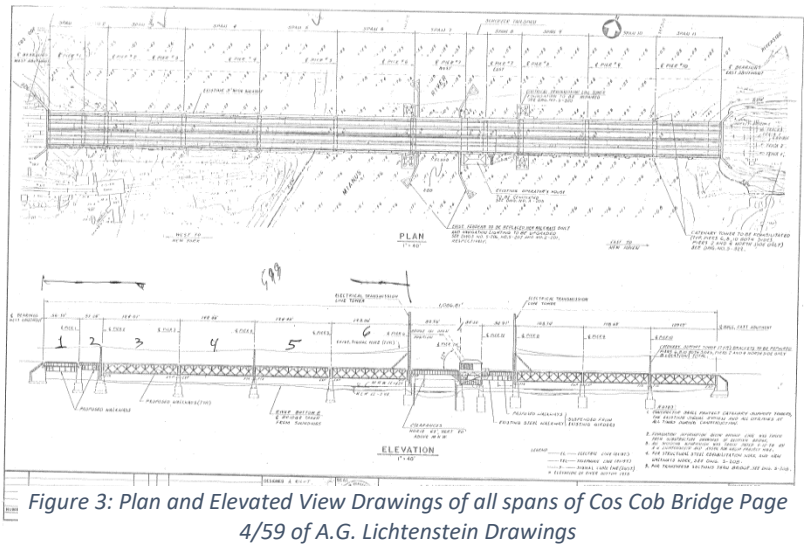

Figure 3: Plan and Elevated View Drawings of all spans of Cos Cob Bridge Page 4/59 of A.G. Lichtenstein Drawings

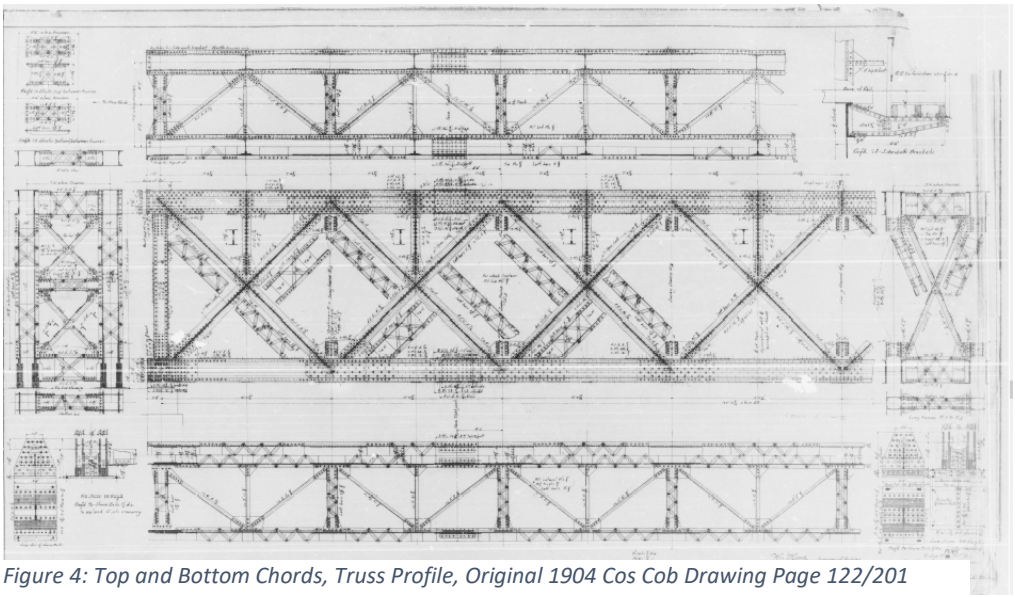

Figure 4: Top and Bottom Chords, Truss Profile, Original 1904 Cos Cob Drawing Page 122/201

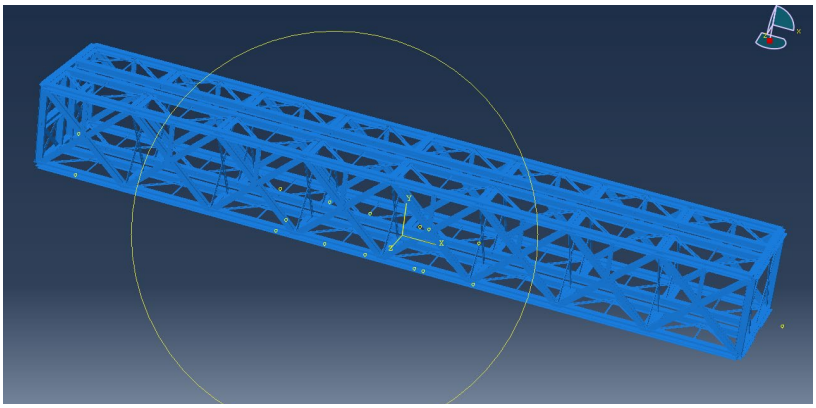

Figure 5: Track 2 and 4 of Span 3 of Cos Cob Bridge

team is using the software ABAQUS to model the Cos Cob Bridge spans. The finite element model of one of the 11 spans (Span 3) of the bridge is shown in in Figure 5.

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

The overarching goal of this project is concerned with the condition/health monitoring, durability and safety of railroad bridges. To determine the currently existing material stress-strain behavior of the structures is critically important for such purposes. Therefore, the material testing of the existing aged railroad bridges to determine current yield and ultimate strength and to obtain the stress-strain relation under loading directly and significantly contribute to the overall goal of the project. The material properties observed under test will be used in the FE model. We have sets of unstressed material and stressed material from different parts of truss and girder bridges all put into service within 10 years of each other. The team hopes to be able to develop an accurate fatigue accumulation function that can be utilized to make the model represent the actual current fatigue state of the bridge. With this accurate model factored into an accurate FE model the team hopes to be able to simulate different loading conditions, especially considering that of increased speed, and observe how the bridge performs and how its fatigue accumulation is affected.

Accomplishments achieved under the project goals:

- From the tests performed thus far, the baseline tensile stress-strain material behavior for the 115 year old Cos Cob steel railroad bridge in Connecticut, has been determined. Testing methods have been established and validated. More tensile and fatigue tests on materials from steel railroad bridges around the New England states as available is planned.
- The scope of a methodology for a continuous monitoring system has been focused to consider utilizing S-N curves and remaining life ratios based on material testing and FE modeling to determine the total remaining life of the most critical members of railroad bridges.
- The team is on track to be able to continue material testing of other bridges. The team expects to be receiving lead free material from the DEVON, Cos Cob, and Atlantic Street Railroad Bridges, all in CT and lead free material from the Ashland Railroad Bridge in Maine.

- Lead Paint Removal was a main cause of delay for the bridge material testing in the lab for many months. The team and the appropriate departments at UConn have established an agreed upon process that will expedite the time between collecting material and procuring coupons. It is the team's hope and belief that lead paint removal will no longer be as much of a problem and cause of delays.
- The team has performed thorough reviews of the three sets of drawing provided by ConnDOT. The team has established a geometrically accurate FE model of one span of the bridge and will continue to build on that toward developing a model of trains traversing this bridge.

Table 1: Task Progress

Task Number	Start Date	End Date	Percent Complete
Task 1: Literature search and review; communication with New England state DOTs for railroad bridge material collection and information/data	10/01/2018	06/01/2019 (proposal) 06/01/2020 (expected) (See section titled "**Changes"** below for the explanation of the change in intended end date)	Thorough literature review of railroad bridge in the New England states has been accomplished. The team's goal is to obtain material from RR bridges from all of the NE states. No opportunities for material collection from NH, RI, and VT have been identified yet. – 75%
Task 2: Existing railroad bridge material testing	01/01/2019	12/31/2019 (proposal) 09/30/2020 (expected) (See section titled "**Changes"** below for the explanation of the change in intended end date)	This task is dependent on the material identified and collected per task 1. Some sample material testing has been done and the results were presented in the year-end report due 09/30//2019. Team will be receiving more steel RR material from CT, Maine, and Mass for test. Still hopeful that bridge material from NH, RI, and VT also be available for testing. – 25%
Task 3: Finite Element (FE) modeling of railroad bridge	06/01/2019	05/30/2020 (proposal) 12/31/2020 (expected) (See section titled "**Changes"** below for the explanation of the change in intended end date)	The team has begun FE modeling of one CT railroad bridge at this time. The FE model will be created as accurately and thoroughly as possible. The moving load simulation/process will be established. Results will need to be validated with field testing per task 5. (10%)

Table 2: Budget Progress

Entire Project Budget	Spend Amount	Spend Percentage to Date
$498,000	$127,256.38	25.55% (12/31/2019)

Opportunities for training/professional development:
Since the research results are still preliminary, no training/professional development opportunities have been provided yet.

Activities involving the dissemination of research results:

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

Title	Event	Type	Location	Date(s)
"Energy Harvesting from Bridge Vibrations, and Railroad Bridge Analysis and Field	Undergraduate ENGR 1000 (Orientation to Engineering) Class	Seminar/Guest lecture presented by Prof. R. Malla	University of Connecticut, Storrs, CT	November 08, 2019

Testing" by Ramesh B. Malla, Ph.D.				
"Railroad Bridge Live Load Impact Factor and Train Speed," by D.W. Jacobs and R. B. Malla	32nd Rhode Island Transportation Forum,	Forum/Conference	Rhode Island Transportation Research Center, University of Rhode Island, Kingston, RI	October 25, 2029

Table 4: Publications and Submitted Papers and Reports

Type	Title	Citation	Date	Status
Journal Paper	Live Load Response of Eyebars on a Very Old Steel Truss Railroad Bridge	Jacobs, D.W., Dhakal, S., and Malla, R. B., "Live Load Response of Eyebars on a Very Old Steel Truss Railroad Bridge." *ASCE Journal/ Practice Periodical on Structural Design and Construction*	Paper submitted 10/20/2019	In Revision
Conference Paper	Determining response of a Railroad Bridge using Limited Number of Sensors	Dhakal, S., Tripathi, S., and Malla, R.B. "Determining response of a Railroad Bridge using Limited Number of Sensors," 37th Annual International Bridge Conference, to be held in Pittsburgh, PA, June 8-11, 2020	Abstract submitted 10/21/2019	In Review
Conference Abstract	Railroad Bridge Live Load Impact Factor and Train Speed	Jacobs, D.W. and Malla, R.B., "Railroad Bridge Live Load Impact Factor and Train Speed," Proceedings of the 32nd Rhode Island Transportation Forum, Rhode Island Transportation Research Center, University of Rhode Island, Kingston, RI; Oct. 25, 2019	October 25, 2019	Published

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	TIDC Advisory Board/ CT DOT contact

		Newington, CT	
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

Students who have participated in the project:

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 Student

Organizations that 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
ConnDOT Contact persons: (1)Andrew Mroczkowski-TIDC Advisory Board, Transportation Engineer III (2) Haresh Dholakia- Transportation Engineering Supervisor (3) Mr. Manesh Dodia- Transportation Engineer III	Newington, CT		X	X	X	X

(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
ATANE, Inc.- Contact person: Kevin Conroy- Project Manager	Wethersfield, CT					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:						X

(1) Dr. Kate Wilson- TIDC Advisory Board, Principal Engineer (2) Donald Murphy- Senior Civil Engineer						
Vermont DOT Contact person: Dr. Emily Parkany- TIDC Advisory Board, Research Manager						X
NH DOT Contact Person: (1) Robert Landry- TIDC Advisory Board, Bridge Design Administrator (2) John Robinson- Railroad Safety Inspector/Investigator						X

Changes:

Discuss any actual or anticipated problems or delays and actions or plans to resolve them…

Collecting and procuring railroad bridge material into coupons for testing has turned into a huge logistical issue. All of the railroad bridge materials the team has identified had lead paint on them. The University and state of Connecticut have very strict guidelines when it comes to removing lead paint. The realization of these guidelines unfortunately has been a tedious process for both the research team, the procurement people at UConn, and the Environmental Health and Services department. In the previous report it was reported that we expect to obtain lead-free steel railroad bridge materials from Metro-North. However, they were unable to remove the lead paint completely. The team is now limited to using University-approved lead paint abatement companies. There are only 4 of these companies and it has been very difficult to communicate with these companies and to get quotes from them. The company AAIS was finally identified and we negotiated a PO with them. All of the material has been delivered to them. The team has reporting about these lead paint removal issues since the summer. This type of material processing and testing from railroad bridge material is novel to the university and many of the logistical issues were learning experiences for everyone. The delays in the end dates are causes of the delays relating to material testing and the time required to remedy the issues and develop a process that satisfies all relevant departments at UConn.

Discuss any changes in approach and the reasons for the change…
- None

Planned Activities for next 3 months:
Description of future activities over the coming months.

- The research team will complete detailed finite element model of the Cos Cob Bridge and a simulation of the dynamic train loading. An effective FEM model will be developed to obtain the response (stress/strain, displacement) under the trains' dynamic loadings on the bridge.
- The research team will continue to maintain communication with the DOTs in New England in search for railroad bridge material and input to our project.
- The research team will procure tensile and fatigue coupons from the lead abated steel from the Cos Cob, Atlantic Street, and Devon Railroad Bridges (all in Connecticut), and from Maine DOT and perform material testing (tensile and fatigue) per the ASTM standards.