Semi-Annual 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 UTC-TIDC
Co-PI(s): N/A
Reporting Period: April 01, 2019 to September 30, 2019
Date: September 30, 2019

Overview:

Overview and summary of activities performed during this reporting six months:
Research work performed over this reporting period has been aligned with Task 1 and Task 2 of the proposal. Per task 1, additional information through literature search relevant to this project about railroad bridges in various New England states has been gathered and analyzed. The research team has communicated with all 6 New England DOTs (CT, MA, ME, NH, RI, and VT) requesting sample railroad bridge material for laboratory tensile and fatigue testing as part of task 2.

Per task 2, the effort has been to collect railroad bridge material has been collected and procured into coupons for fatigue and tensile testing. The team is focused on how the material properties of aged steel from bridges has changed over time. The initial tensile tests performed have been on unstressed A7 material from the Cos Cob Bridge in Greenwich, CT (built 1904).

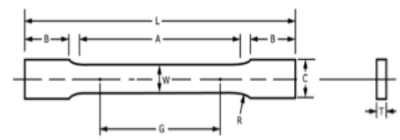

Fig 1: Drawing of tensile coupon ASTM E8

Figure 1 shows the tensile test specimen as per ASTM standard and Figure 2 shows test coupon mounted on the test machine. Results have shown that this aged A7 material has maintained its linear yielding behavior, and its strain hardening and plastic deformation characteristics (Figure 3). Results have also shown that the given ultimate tensile strength (UTS) for A7 steel of 60 ksi did not match the results from tensile testing. Tensile testing has consistently shown a UTS of 50 ksi (Figure 4).

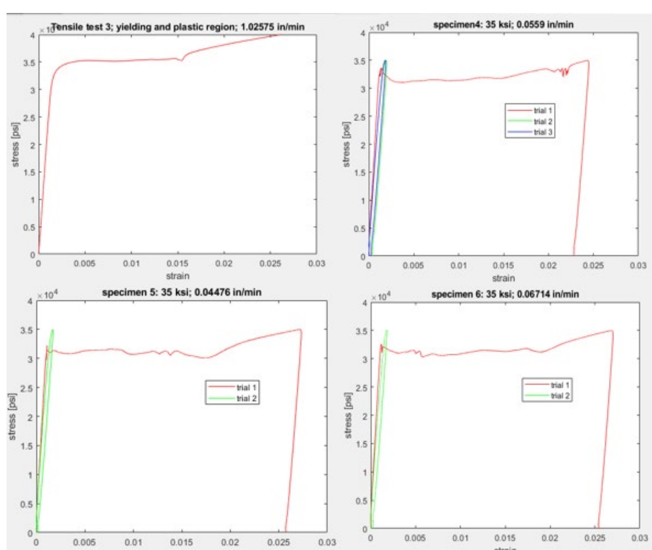

Figure 3: Yielding, Strain Hardening, and Plastic Deformation behavior

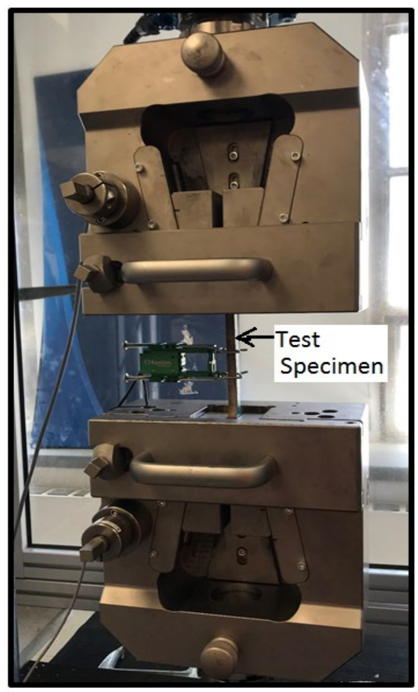

Fig 2: Specimen in Admet Test Set

Referring to Figure 3, tensile test 3 did not incur any reloading and unloading at the stress level of 35 ksi as did tensile speciments 4-6. Referring to figure 2, it can be observed that specimen 3 incurs its strain hardening and plastic deformation during the actual test to break the specimen. This material appears to yield at a lower stress than specimens 4-6 which underwent strain hardening. Further testing will explore if stressing material through its strain hardening actually permanently increases its yield strength.

A few more tests were performed in the linear region for each specimen. For each set of tests, specimens 3-6 were loaded and unloaded by increments of 5 ksi. The loading and unloading were done at least twice at each maximum stress level. Three different strain rates were also used to determine the effect of that parameter. ASTM E8 (2016) suggests a strain rate of (0.015+/-.03 [in/in/min]). These series of tests proved to show that this material behaves as expected with A7 steel and the given strain rates from ASTM E8 are a good choice because there was negligible differences observed between these tests. Their moduli of elasticity are between 190 and 210 GPa based on the tests in the linear region (Figure 5).

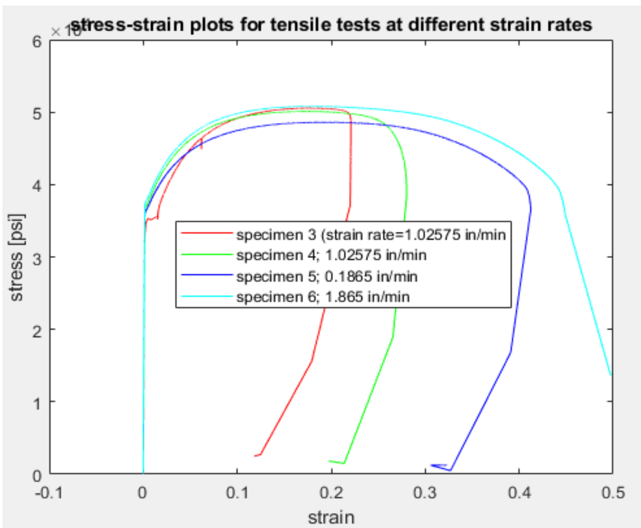

Figure 4: Tensile tests specimens 3-6

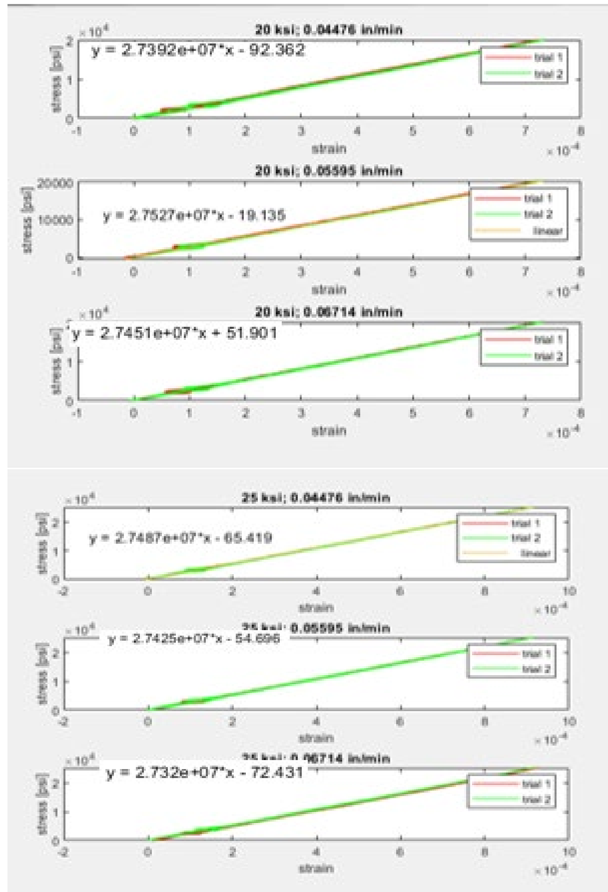

Figure 5: Testing in Linear region

How these activities are helping achieve the overarching goal of the project:
The overarching goal of this project is concerned with the condition/health monitoring, durability and safety of railroad bridges. 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.
Further tensile and fatigue tests of more New England railroad bridges are needed and that is planned in the future as the material become available from various state DOTs.

Accomplishments achieved under the project goals:
From the test so far, th 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 to determine the total remaining life of the most critical members.

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

Activities involving the dissemination of research results:
The research team accomplished dissemination of research results through several avenues during this reporting period.

(a) Conference Presentation and attendance:

- PI Dr. Ramesh B. Malla presented an oral presentation titled "Condition/Health Monitoring of Railroad Bridges for Structural Safety, Integrity, and Durability at the TIDC conference at University of Maine from June 6, 2019 to June 7, 2019.
- Graduate Student Mark Castaldi presented a poster titled "Material Testing of 115 Year old Steel from Cos Cob Railroad Bridge in Greenwich, CT" at the TIDC conference at University of Maine.
- PI Dr. Ramesh B. Malla gave a presentation as a Keynote Lecture at the 12th ASNEngr Annual Conference in Chicago, July 27-29, 2019. The title of the presentation is "Response Monitoring of a Very Old Truss Railroad Bridge for High Speed Trains."
- PI, Dr. Malla attended the ASCE Engineering Mechanics Institute (EMI) Conference held at the California Institute of Technology (Caltech), Pasadena, CA during June 18-21, 2019. This conference is held every year and is internationally prominent and highly respected conference that has many technical sessions related to transportation infrastructure areas. The PI learn from others as well as share his own knowledge on the current state-of-the-art knowledge and technology, know-how and current trend that have direct impact and benefits to the UTC-TIDC project topics at UConn.
- A paper on "Behavior of Eyebars on a 110-year-old Truss Railroad Bridge" co-authored by Dr. Malla with his another graduate student Mr. David Jacobs was presented at the International Bridge Conference, held at National Harbor, MD; June 10-12, 2019,
- PI, Dr. Malla also attended the 2019 Northeast Connected and Automated Vehicle (NECAV) Summit held in Hartford, CT; July 12-13, 2019. He had discussion with the Commissioner of Connecticut DOT, Mr. Joseph Giulletti, several engineers from DOTs, and industry personnel about the UTC-TIDC projects and had opportunity to learn about the current needs in this area that will help strengthen the practical application the projects done at UConn under TIDC.

(b) Peer Reviewed and Other Highly Regarded Publications:

PI Dr. Ramesh B. Malla and his graduate students, who have been studying impact factors of railroad bridges and the potential of allowing high speed trains to travel on the existing bridges in the New England area, have published the following articles in jouranal, conference proceedings, and professional society magazine:

Journal:

Jacobs, W. and Malla, R. B " On live load impact factors for railroad bridges," *International Journal of Rail Transportation*, Vol. 7, Issue 4; April 2019; pp 262-278; (online - https://doi.org/10.1080/23248378.2019.1604182)

Conference Proceedings:

Jacobs, D.W., Dhakal, S., and Malla, R. B., "Behavior of Eyebars on a 110-year-old Truss Railroad Bridge," *Proceedings, International Bridge Conference*, Engineers' Society of Western Pennsylvania (ESWP), Pittsburgh, PA; Aug. 2019; 592-599 (Full-length- reviewed)

Highly regarded Professional Magazine

Jacobs, D. W. and Malla, R. B., " Eye Strain," RT&S- Railway Track and Structures, Vol. 115. No. 9, New York, NY, Sept. 03, 2019, pp 12-19

(c) Meeting with DOTs:

Results, conclusions, advanced methodologies, and future activities were discussed with Connecticut Department of Transportation (CT DOT) on June 28, 2019 during a meeting with the Rail Division. The Conn DOT has offered their help to work with the research team in the project. They have identified the points of contact for the project.

Participants and Collaborators:

The core research team members for this project are:

- Prof. Ramesh B. Malla, Ph.D., Principal Investigator
- Mark Castaldi, Graduate student, Mechanical Engineering
- Sachin Tripathi, Graduate student, Civil & Environmental Engineering (new)

Although not directly funded under the UTC-TIDC project, the following students are receiving research and educational experience in the areas of the railroad bridge research under Professor Malla's supervision:

- David Jacobs, Ph.D. student, Civil / Structural Engineering working on research related to the impact factor of railroad bridges (formerly, Manager at Metro-North Railroad Company)
- Suvash Dhakal, Ph.D student, Civil/Structural Engineering working on research related to monitoring railroad bridges (also currently with A. DiCesare Associates, P.C, Bridgeport, CT.),
- Francis Almonte, Graduate Student, Materials Science & Engineering (Custodian of the Materials Science lab that has been utilized for tensile and fatigue testing)
- Stephanie Kreitler, Undergraduate Junior, Civil Engineering (independent research study on moving load analysis of a railroad bridge.)
- Sean Doolittle, Undergraduate sophomore, Chemical Eng. (Honors' project on railroad bridge truss analysis)
- Liam Gerety, Undergraduate Sophomore, Material Science and Eng. ((Honors' project on railroad bridge truss analysis)

Organizations involved as partners on this project

- CT Department of Transportation (Conn DOT) (Contacts: Mr. Andrew Mroczkowski, TIDC Advisory Board, Transportation Engineer III; Mr. Haresh Dholakia, Transportation Engineering Supervisor; Mr. Manesh Dodia, Transportation Engineer III; Mr. Edgardo Block, Manager, Research unit; and John Bernick, Assistant Rail Administrator)
- Metro-North Railroad Company (Contact: Warren Best, P.E., Assistant Deputy Director-Structures, Mr. Nick Watert, Engineering Supervisor- Structures)
- ATANE Consulting (Contacts: Mr. Kevin Conroy, P.E.)
- In addition to CT DOT as listed above, the research team is also currently in communications and is collaborating with all other New England DOTs to acquire steel bridge material for testing through the respective TIDC Advisory Board representatives:
    - Maine Department of Transportation (Maine DOT) (Contacts: Mr. Dale Peabody, Director, Transportation Research, Augusta, Maine, and Mr. Brian Reeves, Director, Rail Transportation)
    - Vermont Agency of Transportation (Contact: Dr. Emily Parkany, Ph.D., P.E., TIDC Advisory Board, Research Manager)
    - Rhode Island Department of Transportation (Contact: Dr. Kate Wilson, TIDC Advisory Board, Principal Engineer)
    - New Hampshire Department of Transportation (Contact: Mr. Robert Landry, TIDC Advisory Board, Bridge Design Administrator)
    - Massachusetts Department of Transportation (Contact: Mr. Brian Clang, TIDC Advisory Board, State Bridge Inspection Engineer)

Changes:

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 bridge material the team has received has lead paint on it. 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 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 a lot of lead-free steel from Metro-North. However they were unable to remove all of the lead paint. 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. one company provided very high quote (nearly $5,000) and the team has been waiting for weeks to hear back from these other companies despite multiple efforts to motivate them to provide quotes.

Changes in approach and the reasons for the changes:
Because of all of the delays relating to material testing, it has recently been decided that efforts will be now more focused on the next task of developing a finite element model of a representative old New England railroad bridge. The Cos Cob Railroad Bridge in Greenwich, CT has been selected for this. The design drawings for this bridge have been received from CT DOT.

Planned Activities:

Description of future activities over the coming months.

- The research team will be focused on creating a 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 team is also interested in observing if it is possible to determine the response of the structure at some limited number of locations and be able to predict the response of the entire bridge. This could be useful in determining the key locations to place a limited number of sensors to gain the total response of the bridge. The research team is also interested in developing a methodology for converting the complicated structure of the bridge to a more simplified model.

- The research team will continue the effort to get material from the Cos Cob, Atlantic Street, and Devon Bridges in Connecticut lead paint abated so further material testing can be performed. The material tests will also resume once the research teams start receiving materials from other New England states in the future.

References:

ASTM (2016), "ASTM E8/E8M-16a Standard Test Method for Tension Testing of Metallic Materials." ASTM International, West Conshohocken, PA, 2016, https://www.astm.org/Standards/E8.htm (Date Accessed: Feb. 11, 2019)