<u>Bi-Monthly Progress Report</u>:
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
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Co-PI(s): N/A
Reporting Period: April 01, 2019 - May 31, 2019
Date: May 31, 2019

<u>Overview:</u>

Overview and summary of activities performed during previous two months
Research work performed over this reporting period has been aligned with Task 1 and Task 2 of the proposal. Per task 1, information relevant to this project about railroad bridges in various New England states is to be gathered and analyzed. Per task 2, New England railroad bridge materials are to be collected and samples are to be prepared and tested per the ASTM standards. Research has been focused on being able to utilize available bridge information and integrate that into the conclusions drawn from material testing.

Thus far, the bridge material members that have been collected are two large bracing support beams to support the foot bridge along the 115-year old Cos Cob railroad bridge in Greenwich, CT. These members have areas that appear rust free and areas that are corroded and rusted. To date, testing has been performed on limited number of test coupons cut out from the rust free areas. Tensile specimens were prepared and tested per ASTM E8/E8M-16a (2016) Fatigue specimens were prepared and tested per ASTM E466-15 (2015). 6 Tensile Tests and 1 Fatigue test have been performed for this material (Fig. 1& 2). Tensile Testing has revealed that this 115-year old non-rusted A7 steel has maintained its elastic, yielding, plastic deformation, and strain hardening characteristics. However, testing proved that the strength properties after strain hardening has worsened. A7 steel has been described as a wear resistant low strength material. It certainly is wear resistant, but its low strength characteristics worsened. The given value for the UTS of A7 steel is 60-70 ksi. For 5 of the 6 tensile tests the UTS was around 50 ksi (Fig. 3).

Testing in the linear region involved loading and unloading incrementally up to the yield point. Different strain rates were used. There was not much of an effect of the strain rate on the results. The value and tolerance for the strain rate from ASTM E8/E8M-16a was used (0.015+/-.03 [in/in/min]). Figure 4 shows the consistent young's modulus measured at different loadings and different strain rates. All testing has shown that the young's modulus is between 2.7 and 3.1 E7 psi (186-213 GPa). The given Young's Modulus for A7 steel is 190-210 GPa. Figure 5 shows the yielding and plastic regions for specimens 3-6. The behavior in these regions is very similar to that given for A7 steel. Performing repetitive loading and unloading to stress levels below the yield stress has proven to not affect the young's modulus, yield stress, plastic deformation and strain hardening characteristics of the steel. However, once the material has been stressed beyond its yield stress, its properties change as expected. The young's modulus slightly decreases, and its fracture behavior changes. Tests thus far have

Figure 1: 150 kN rated ADMET test set

Figure 2: Tensile Specimens 1-6; Fatigue specimen 1

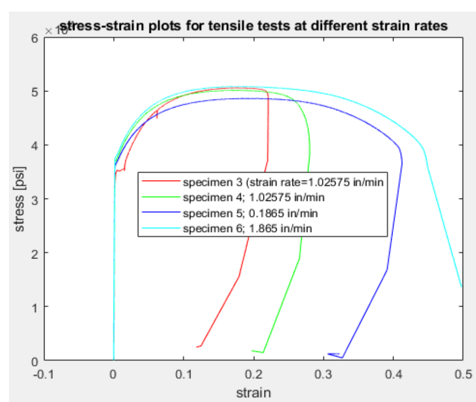

Figure 3: Tensile Tests 3-6

shown that specimens that were subjected to repetitive loading beyond the yield stress incurred more strain before breaking, though their ultimate tensile strength (UTS) still matched that of specimens that did not experience repetitive loading beyond the yield stress.

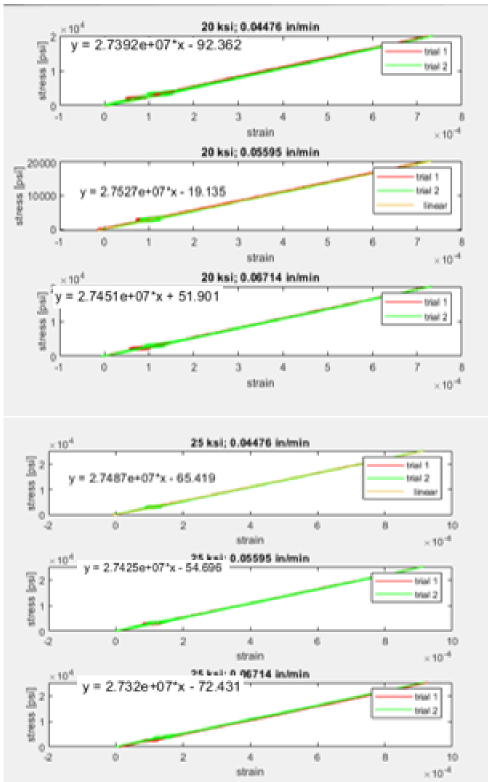

Figure 4: Testing in Linear region

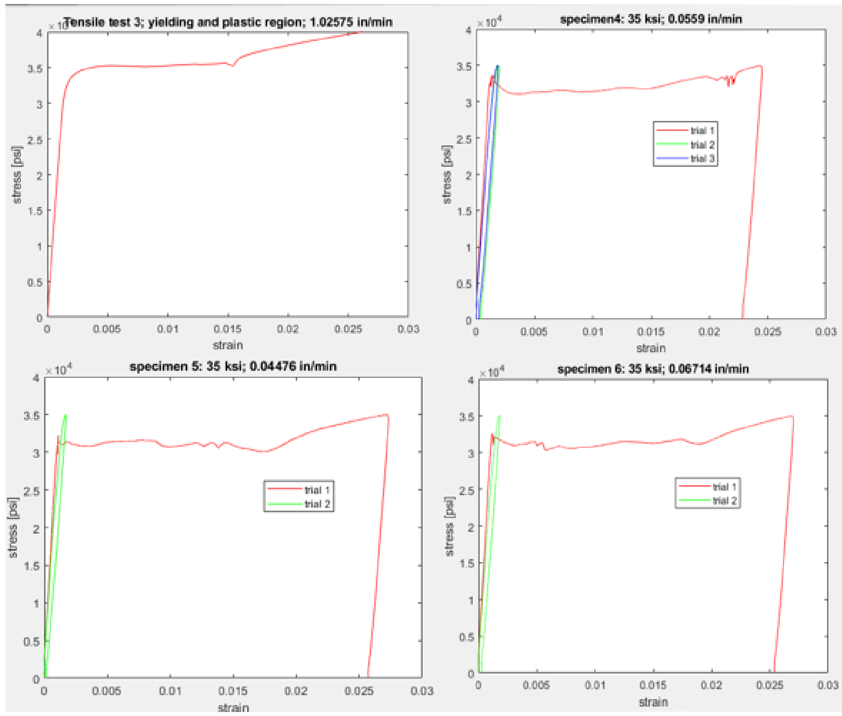

Figure 5: Yielding and plastic regions

How these activities are helping achieve the overarching goal of the project

Testing thus far has sparked the concept that steel bridge member's material properties should not worsen over time unless rust and corrosion is involved or unless the member has been stressed beyond its yield stress. Seeing the material properties before the UTS value remain the same as compared to the given values for A7 steel and seeing the material behave so consistently between the 6 tensile tests gives confidence in the expected behavior of steel. This confidence has led to the concept that the team's structural health monitoring system could involve developing time histories of loading to predict the accumulated fatigue for each member, then further sensing and comparison to the material's S-N curve can give an estimate for the remaining life for these members.

Accomplishments achieved under the project goals

Baseline material behavior for 115 year old nonrusted A7 steel has been determined with confidence for the samples collected thus far. This will be compared to rusted sections of A7 steel and other types of steel from other bridges. Testing methods have been honed and validated. The scope of a methodology for a continuous monitoring system has been focused to consider utilizing S-N curves and load/time histories of railroad bridges to determine remaining life for 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 project is still in its initial phase. However, some of the preliminary research results were disseminated during the TIDC workshop on November 8-9, 2018 in Portsmouth, NH. Additionally, on February 28, 2019 the research team met with Conn DOT in Storrs, CT and presented on the projects and shared the information currently achieved. As more results become available, the research team aims to dissemination research results via journal and conference publications, seminars/conferences/workshop presentations, and other appropriate avenues. Research team will present an oral presentation and a poster containing methodology, results, conclusions, and future activities at the US DOT Region 1 UTC -TIDC Annual Conference being held at the University of Maine, Orono, ME during June 6 and 7, 2019.

Participants and Collaborators:

The main contributors to the core of this project are:

- Prof. Ramesh B. Malla, Ph.D., Principal Investigator
- Mark Castaldi, Ph.D student, Mechanical Engineering

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 study research 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)
- Maine Department of Transportation (Maine DOT) (Contacts: Mr. Dale Peabody, Director, Transportation Research, Augusta Maine, Mr. Brian Reeves, Rail and Freight Project Manager)
- Metro-North Railroad Company (Contact: Warren Best, P.E., Assistant Deputy Director-Structures)

Discussion with the following have been initiated

- Amtrak (Contact: Mr. Paul L. DelSignore, Deputy Chief Engineer-Structures, Amtrak, Philadelphia, PA)
- Providence and Worcester Railroad company (Contact: Mr. Todd Dragland, VP Engineering, GWRR NE Region, Stamford, CT)

Changes:

Actual or anticipated problems or delays and actions or plans to resolve them

The railroad bridge members collected from the Cos Cob are covered in lead paint. It is likely that most of the material we receive will be covered in lead paint. Ph.D. Student Mark Castaldi is in the process of going through the necessary EHS trainings required for lead paint removal. When the training is complete, Mark will be able to remove the lead paint from the sections of members that the team wants to test.

Planned Activities:

Future activities over the coming months include:

(1) More material from railroads in New England region will continue to be collected, test specimens will be fabricated from them, and r tensile and fatigue tests will be conducted.

(2) Experimental results will be analyzed and inference will be drawn.

(3) An Attempt will be made to Using Miner's Rule, determine the remaining life based on the maximum stress incurred from loading.

References:

ASTM (2015). "ASTM E466-15 Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials." ASTM International, West Conshohocken, PA, 2015, https://www.astm.org/Standards/E466.htm (Date Accessed: Feb. 23, 2019)

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)

ASTM (2017), "ASTM E1049-85 Standard Practices for Cycle Counting in Fatigue Analysis." ASTM International, West Conshohocken, PA, 2017, https://www.astm.org/Standards/E1049 (Date Accessed: May 7, 2019)