TIDC Transportation Infrastructure Durability Center AT THE UNIVERSITY OF MAINE

<u>Quarterly Progress Report</u>:
Project Number and Title: Thrust #1 Distributed Fiber Optic Sensing System for Bridge Monitoring
Research Area: Thrust #1
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Co-PI(s): TzuYang Yu, Civil Engineering Department, University of Massachusetts Lowell
Reporting Period: 01/01/2020-03/31/2020
Submission Date: 03/31/2020

<u>Overview:</u> (Please answer each question individually)

A field test was performed on a railway bridge (Salmon Falls River bridge) which locates at South Berwick, New Hampshire. Sensing textile was used to improve the installation of the fiber on the bridge. The fiber was sewed with the help of Saint Gobain. Figure 1. Shows the location and side view of the infrastructure which is a deck truss bridge with a span of 102 ft and a width of 60 ft.

Figure 1. Salmon Falls River bridge in South Berwick

The installation of the sensors consisted in different procedures. In order to ensure a complete bonding between the optical cable and the surface all dust and rust had to be removes. This was done using an electrical polisher and acetone to remove the dust. After the corrosion was removed, the optical fiber was glued to the surface using epoxy. Finally, the fiber was connected to the BOTDR for data measurement.

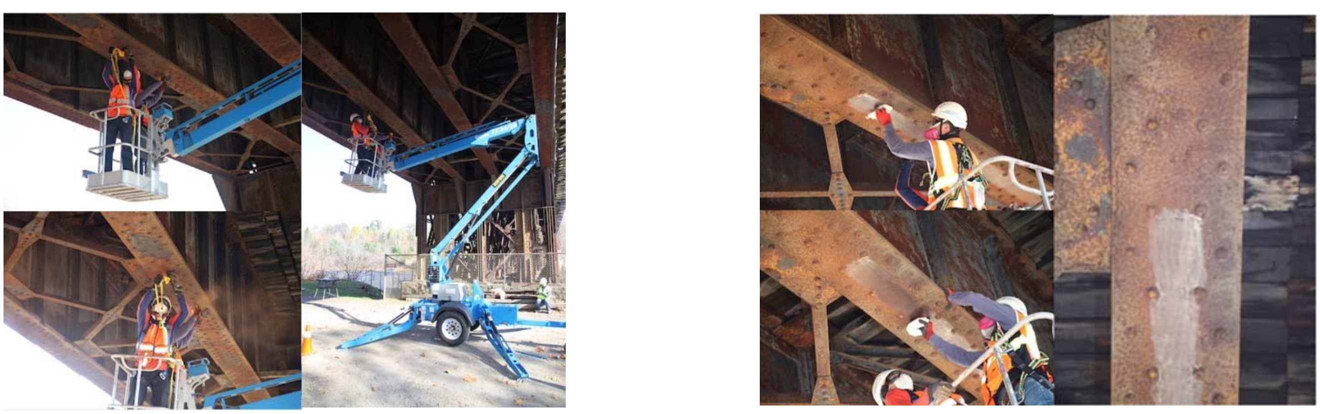

Figure 2 Polishing steel plate and cleaning plates with acetone

Figure 3 Attaching optical sensor with epoxy and connecting sensor to BOTDR

Test design

The idea for this test was to measure trains passing by at different times of the day and observe if the sensing textile could acquire the strain generated by the bridge due to the train. Two different trains are expected to use for this test. The first one is the Amtrak and the second one is a freight train. BOTDR data will be collected using 5MHz step frequency. The measurements will have a small signal to noise ratio, but the scan time will be shorter allowing to acquire the train passing by the bridge. After the data is collected signal processing will improve the detection system. The first step requires the temperature effect to be removed. This is done by using a section of fiber which is not affected by any type of physical stress.

Figure 4 shows the key section of the signal while the BE part corresponds to the fiber loop fixed on the bridge and free from strain (No physical stress) which is used for temperature compensation. The temperature effect on the system has been studied and tested in our lab and is be given by,

$$\Delta Freq. = 33.54 * (T - T_{baseline}) / 20000$$

The measured frequency signal was compensated to the same temperature level, this reduced the frequency variation caused by temperature while analyzing the loading impact on the bridge.

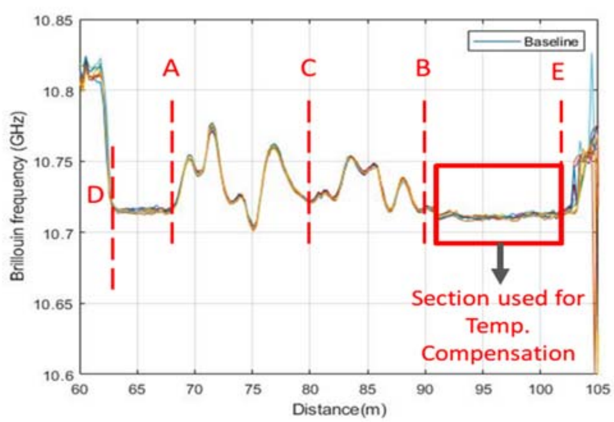

Figure 4 Signal baseline with cured epoxy

Figure 5 shows the relationship between predicted and measured temperature, the average temperature deviation of 10 test was -1.15°F, in which the handheld infrared thermometer has an accuracy of ±0.1°F, and the system accuracy at 1MHz was ±0.7°F according to the data tested in the lab.

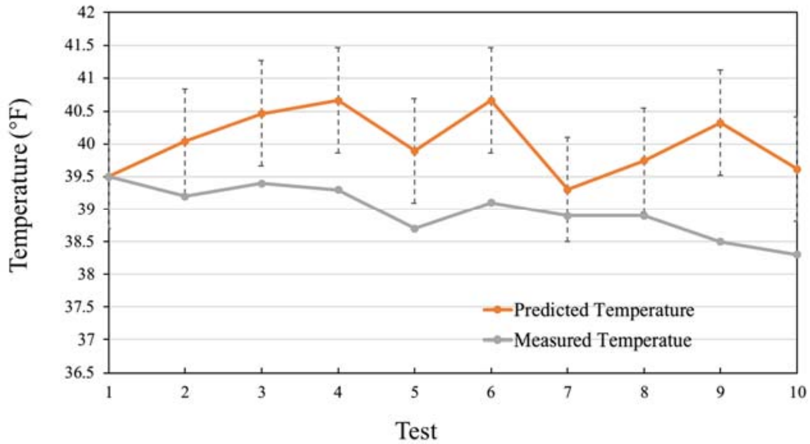

Figure 5 temperature difference between predicted and measured

Strain distribution under uniform light loading

Figure 6 shows the Brillouin frequency response of tests including different conditions (temperature compensated), the Test 1,2 and 3 were tested without train and the step frequency of 1MHz; the Train1 and Train2 were tested under a train and the step frequency of 5MHz. As you can see, the Brillouin frequency amplitude have significant changed under the train passing over the bridge.

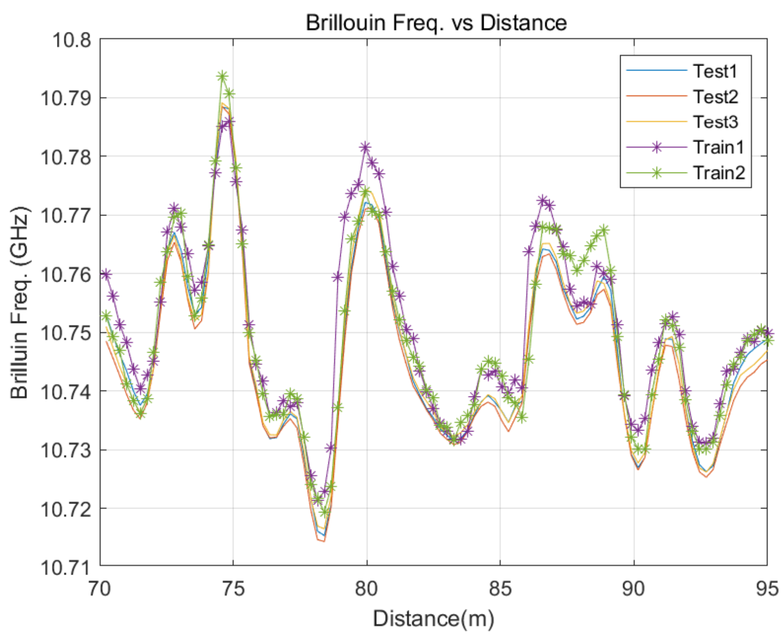

Figure 6 Brillouin frequency response of the sensing fiber in different test

Furthermore, the strain differences at different conditions were shown in Figure 7. The strain differences among the tests without train were at a low level of 2.01 micro strain and -26.1 micro strain average in distance. The strain differences between tests under/without train were up to 87.8 micro strain.

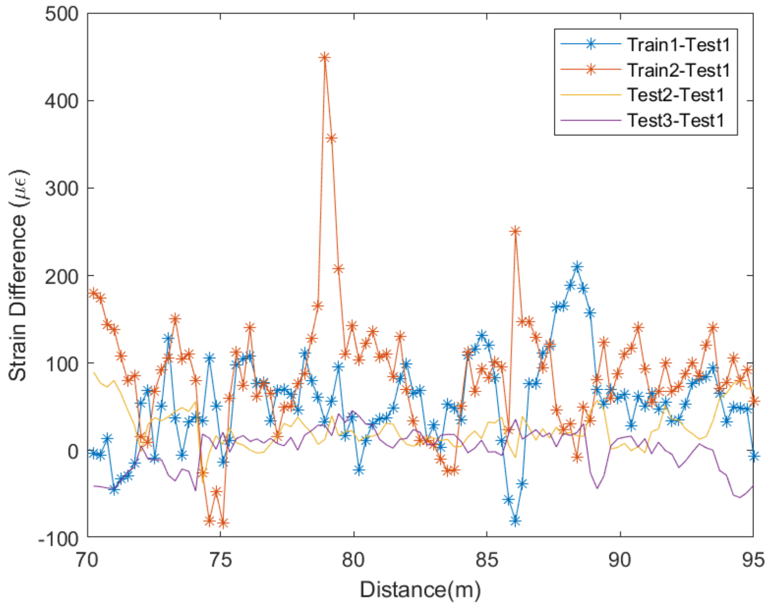

Figure 7 Brillouin frequency of sensing fiber in different tests

Summary

In the application of the BOTDR sensing textiles system in Salmon Falls River bridge, we have successfully installed the sensing textile at the bottom of the bridge and completed testing the Brillouin Frequency signals under different conditions. The strain noise caused by the different system parameters has been studied, and the temperature impact on the system has been analyzed. By comparing the Brillouin Frequency Shift, we were able to indicate the loading condition of the bridge.

Table 1: Task Progress			
Task Number	**Start Date**	**End Date**	**Percent Complete**
Task 1: Sensor development.	1/1/2019	6/30/2019	100%
Task 2: Signal processing and sensor characterization	1/1/2019	12/30/2019	100%
Task 3: Preliminary field test on a bridge	12/30/2019	12/31/2020	70%

Table 2: Budget Progress		
Entire Project Budget	**Spend Amount**	**Spend Percentage to Date**
$102.1k	$ 80k	78%

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**
N/A				

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
	Distributed Brillouin fiber optic sensing textile	Full citation		Submitted to a conference

Participants and Collaborators:

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members			
Individual Name	**Email Address**	**Department**	**Role in Research**
Xingwei Wang	Xingwei_wang@uml.edu	Electrical and Computer Engineering	PI
TzuYang Yu	Tzuyang_yu@uml.edu	Civil Engineering	Co-PI

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
Andres Biondi	Ph D		ECE	Signal analysis
Rui Wu	Ph.D.		ECE	Signal analysis
Xiaoyu Zhang		M.S.	ECE	Test
Xu Guo		Ph.D.	ECE	Test
Qixiang Tang	Ph.D.		Civil Engineering	Signal analysis & Test

Table 7: Student Graduates			
Student Name	**Role in Research**	**Degree**	**Graduation Date**
N/A			

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**
Saint-Gobain	Northborough MA		x			
ARE			X			

Saint-Gobain have been involved in the New Hampshire Bridge selection process by facilitating contact with bridge owners' companies. Also, has part of the data in this report has been collected in conjunction with Saint-Gobain. Authorization has been granted for the used in this report.

Changes:

Until now the project is on track to be finished on time. No change has been presented.

Planned Activities:

Over the coming months the research will focus on continue monitoring the sensors installed in New Hampshire. Also, we will continue to develop the temperature compensation process and improve the signal analysis mechanism.