Quarterly Progress Report:
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: 10/01/2019-12/31/2019
Submission Date: 12/31/2019

Overview: **(Please answer each question individually)**

A repeatability test was carried out on the pedestrian bridge in different time. The data was affected by two components. The first one is related to the parameters used in the BOTDR equipment. Depending on the parameters chosen, the signal to noise ratio varies. The second aspect is the environmental and installation condition. Brillouin Frequency is linearly proportional to strain and temperature. When installed, the glue applied to create a bound between the surface and the fiber exerts strain to the system generating a frequency shift. On top of that, temperature also adds its effect to the signal given and output where the real strain measurement of the structure is hidden among the glue and temperature effect.

The pedestrian Bridge is located at the University of Massachusetts Lowell. It is the bridge that connects Olney Hall and Ball Hall. This bridge is a one-span steel truss bridge with a span of 92ft and a width of 7 ft as show in Fig. 1

Figure 1. Pedestrian bridge at UMASS Lowell

The fiber optic sensing cable was placed at one side of the bridge and a runner mat was added in order to protect the fiber from any damage that could be exerted by people walking on it. Once the fiber installation was done, the BOTDR was connected to the system. Fig 2 shows final set up of the system.

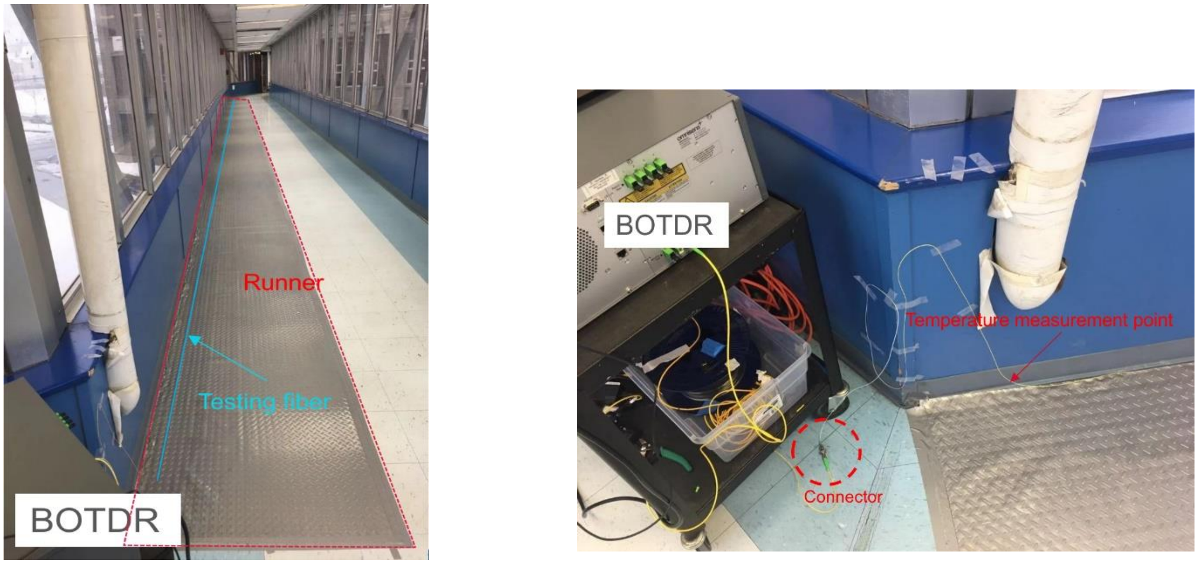

Figure 2 (a) The runner was installed to protect the sensing textile (b) Connection between BOTDR and fiber optic sensors

The total amount of measurements taken during this test was 10. The parameters used are shown in Table 1. Finally, we compared the results with the data collected on July 2019th. By comparing these two data sets, a frequency shift was expected since the temperature difference between both days was significant.

Table 1 BOTDR parameters

Step Frequency (MHz)	Average	Frequency Range (GHz)	Spatial resolution(m)	Sampling Rate (m)
5	5,000	10.7~11	1	0.5

Figure 4 shows the frequency measurement for both tests. Baseline 1 corresponds to the first test (July 2019th). During that test the average temperature was about 77°F. Baseline 2 corresponds to the latest data set (December 2019th) in which the average temperature recorded was 60°F. Since the temperature dropped, it was expected the frequency had a downward shift as shown in figure 3.

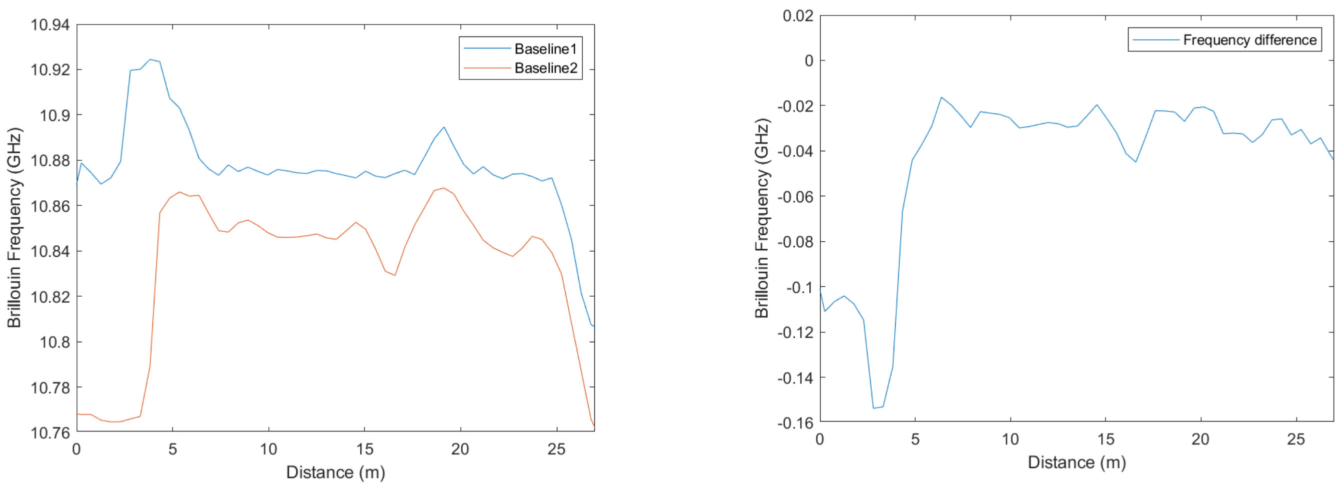

Figure 3 (a)Brillouin Freq. vs Distance (b) Test Freq. difference vs Distance

In order to overcome this effect, a temperature compensation method was implemented. Possible solution consists of adding an external fiber, which is surrounded by a protective gel. This gel isolates the fiber core from any strain inflicted by the structure. Once the exact frequency shift produced by the temperature effect is known, it can be used to compensate the strain data. The other possibility is to use the same fiber but add an external section which is immune to strain, assuming the temperature is similar when the fiber is not very long. Form that section, the frequency shift due to temperature can be known and used to compensate. Further investigation will be performed in the coming months.

The performance of this test improved the knowledge of BOTDR signal measurement by understanding how the frequency shift will behave throughout time. This is an important aspect that needs to be considered for the overall goal of the project, since it is expected that the sensor will remain in the structure for years. Knowing what circumstance will affect the base line signal, allows us to prepare mechanisms to compensate the shift and obtain the true strain signal generated by the structure.

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	6/1/2020	12/30/2019	50%

Table 2: Budget Progress		
Entire Project Budget	**Spend Amount**	**Spend Percentage to Date**

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**
N/A				

Participants and Collaborators:

Use the table below to list all individuals who have worked on the project.

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

Jingcheng Zhou		Ph.D.	ECE	Test
Hao Peng		Ph.D.	ECE	Test
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**
Jingcheg Zhou		Ph.D.	12/2019

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			

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.

<u>Changes:</u>

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

<u>Planned Activities:</u>

Over the coming months the research is focused on the implementation of the fiber into the New Hampshire Bridge located in the Rollinsford town. More details on the bridge and location will be presented in the next report. Also, we will continue developing the temperature compensation process, characterization of different fibers and improving the signal analysis mechanism.