TIDC Transportation Infrastructure Durability Center AT THE UNIVERSITY OF MAINE

Quarterly Progress Report

Project Number and Title: C11 Development of a system-level distributed sensing technique for long-term monitoring of concrete and composite bridges
Research Area: Thrust 1: Transportation infrastructure monitoring and assessment for enhanced life
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Co-PI(s): Susan Faraji (UML), Xingwei Wang (UML), Zhu Mao (UML), Bill Davids (UMaine), Ehsan Ghazanfari (UVM)
Reporting Period: 01/01/2021~03/31/2021
Date: 03/30/2021

Overview:

The research problem we are trying to solve is the long-term monitoring problem of bridges (e.g., concrete and composite bridges), using multiple modes of sensing technology including fiber optic, video motion, and electromagnetic sensors. In the past quarter, we collected baseline data from integrated sensing textile (with fiber optics and strain gauges) on the Grist Mill Bridge (Hampden, ME) during December 30~31, 2020, with and without vehicular truck/live loads. Table 1 provides our progress on individual tasks. Table 2 reports our budget progress. In this quarterly report, we will report our baseline measurements from the Grist Mill Bridge (Hampden, ME).

Table 1: Task Progress

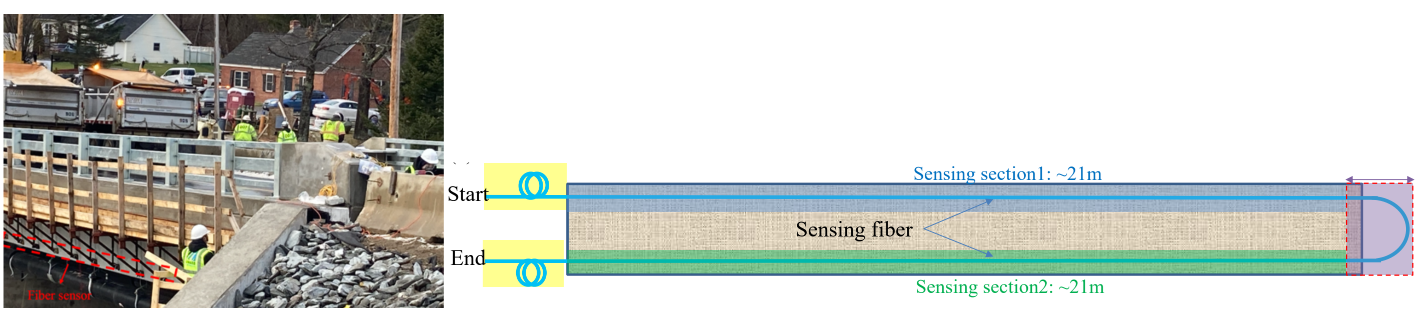
Task Number	Start Date	End Date	Percent Complete
Task 1	01/01/20	02/28/20	100%
Task 2	01/01/20	03/31/20	100%
Task 3	01/01/20	07/31/20	90% (postponed)
Task 4	07/31/20	08/15/20	100%
Task 5	08/15/20	08/20/20	100%
Task 6	08/15/20	12/31/21	10%
Task 7	08/20/20	12/31/21	0%
Task 8	01/01/20	12/31/21	5%

Table 2: Budget Progress

Entire Project Budget	Spend Amount	Spend Percentage to Date
$166,304 (Year 1)	$49,891 (TBD)	30% (estimated)

Baseline measurements on the Grist Hill Bridge (Hampden, ME)

- Optical fiber sensor data – From the functional optical fiber sensors installed on two bridge girders, we have established the baseline measurement of the bridge. Figure 1 a) shows the location of installed optical fiber sensors. Figure 1 b) shows the U-shape layout of optical fiber sensors on the bottom flange of a bridge girder.



a) Installed optical fiber sensors b) Layout of optical fiber sensors
Fig. 1. Installed optical fiber sensors on the Grist Mill Bridge

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Figure 1 b) shows the schematic of the U-shape sensing textile installed along the bridge. As shown in Fig. 2 (b), since the truck loading was applied at the midspan of the bridge, resulted strain distribution was symmetric. In addition, due to the symmetric U-shape of the sensing textile, strain distribution in two sections of the optical fiber was also symmetric. When changing the parking locations of the trucks, different strain distributions are also observed, as shown in Fig. 2. Fig. 6 shows ECE grad students Rui Wu and Lidan Cao collecting field data.

- Stain gauge data – From the strain gauge measurements collected on girder 3 (strain gauge data only) of the bridge, we can see that the strain distribution on girder 3 reflects the change in the location of vehicular truck loads. Fig. 3 demonstrates the feasibility of strain gauge data in detecting change in load distribution.

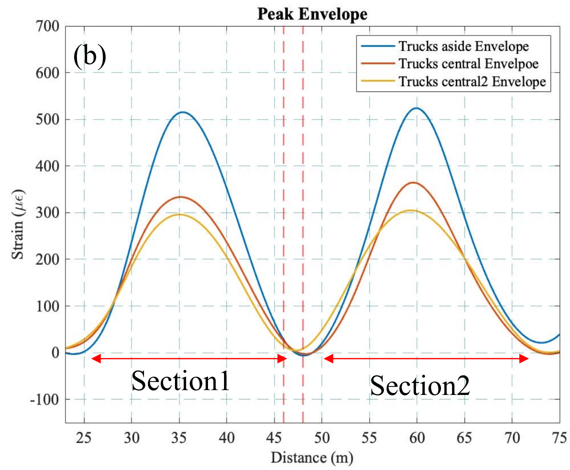

Fig. 2. Baseline and loaded strain responses

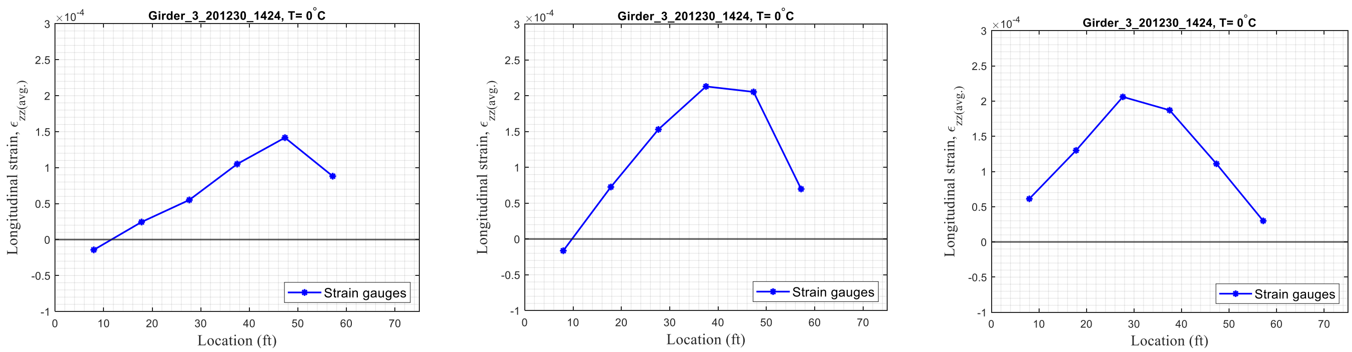

Fig. 3. a) Truck at ¾ span from 0-ft. b) Truck at midspan from 0-ft. c) Truck at ¼ span from 0-ft.

When comparing the data between strain gauge measurement and optical fiber sensor measurement, Fig. 4 shows the similar pattern in the loaded response of the bridge. The difference between strain gauge measurement and optical fiber sensor measurement was mainly due to i) strain gauge measurement is very local but optical fiber sensor measurement is global, and ii) strain gauges are installed ~0.6 inches away from the optical fiber sensors. Figure 6 shows UML CEE grad student Harsh Gandhi collecting field data underneath the bridge.

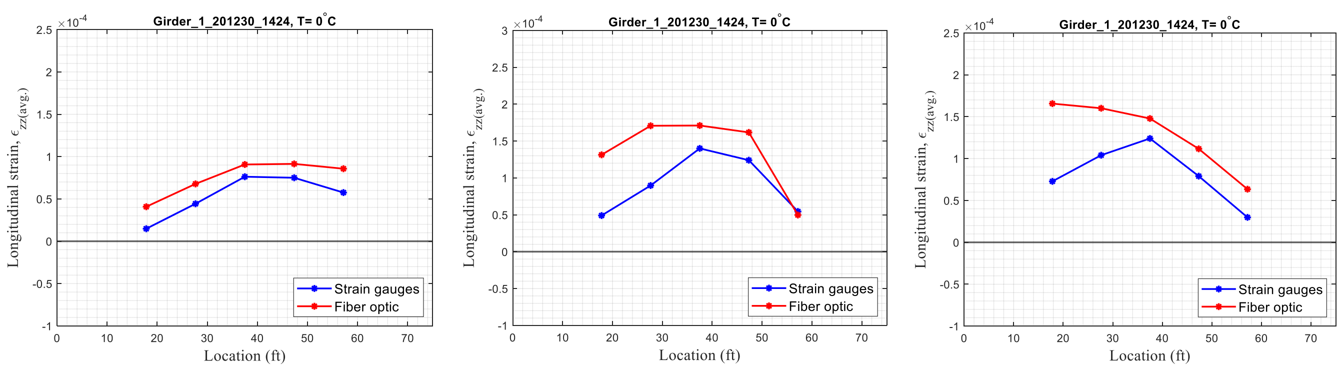

Fig. 4. a) Truck at ¾ span from 0-ft. b) Truck at midspan from 0-ft. c) Truck at ¼ span from 0-ft.

- Video camera sensor data – A video camera was set up adjacent to the bridge in order to extract full-field bridge vibrational motion as Fig. 7 shows. The position of the camera is set to be in the perpendicular direction to maintain a good observation to the whole bridge span. The ambient ground motion is recorded to compensate the shaking of the camera through a low-cost Raspberry Pi microcontroller and two accelerometers as Fig. 8 shows. To avoid aliasing in the frequency domain, the camera frame rate is set to be 60fps, such that all the bridge dynamics up to 30Hz will be recorded. The time-domain ground motion of camera is plotted in Fig. 9. Fig. 10 shows UML ME grad student Celso Do Cabo collecting field data. Fig. 11 a) shows the bridge vibration under a truck running at 30mph. Fig. 11 b) shows the bridge vibration under a truck running at 20mph.

Fig. 6. Grad students Lidan and Rui collecting data. **Fig. 5.** Grad Harsh collecting data. **Fig. 7.** Video camera setup

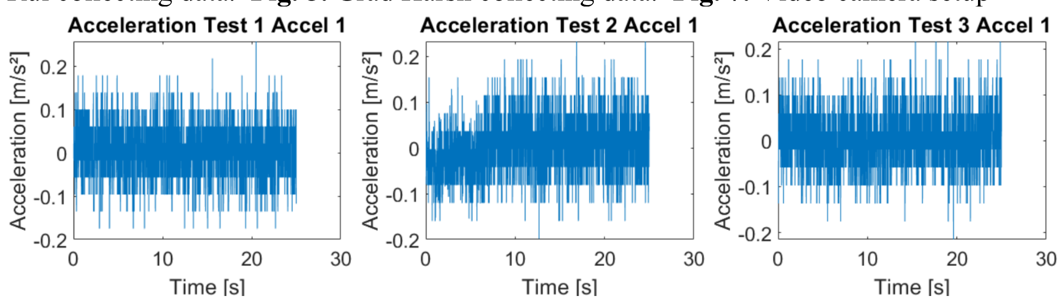

Fig. 8. Raspberry Pi setup. **Fig. 9.** Raspberry Pi time domain response (Y direction)

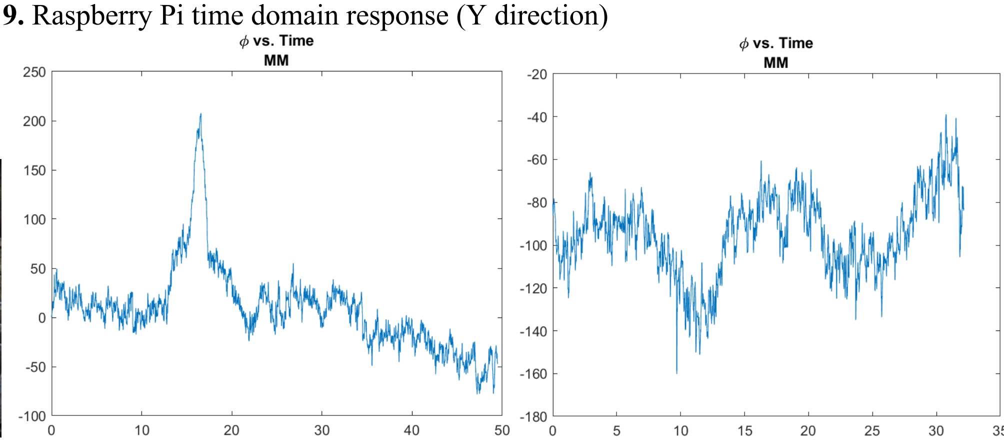

Fig. 10. Grad student Celso collecting field data. **Fig. 11.** a) Bridge vibration at 20mph b) bridge vibration at 30mph

- Radar sensor data – We also used GSSI (Geophysical Survey Systems, Inc.) Utility Scan system collecting the ground penetrating radar (GPR) baseline data of the bridge. We will present the result in our next quarterly report.

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

Title	Event	Type	Location	Date(s)
Optical fiber sensing textile for temperature and strain distributed measurement	2021 SPIE Smart Structures/NDE Conference	Conference presentation, prerecorded	Virtual meeting	March 23, 2021

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
Conference paper	Optical fiber sensing textile for temperature and strain distributed measurement	https://doi.org/10.1117/12.2595377	March 23, 2021	Published

Table 4: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**
Optical fiber sensing textile for temperature and strain distributed measurement	2021 SPIE Smart Structures/NDE Conference	Conference presentation, prerecorded	Virtual meeting	March 23, 2021

Participants and Collaborators:

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members			
Individual Name	**Email Address**	**Department**	**Role in Research**
Tzuyang Yu	Tzuyang_Yu@uml.edu	Civil and Environmental Engineering	Project principle investigator (PI) and Institutional Lead at UML; overseeing all project activities
Susan Faraji	Susan_Faraji@uml.edu	Civil and Environmental Engineering	Co-PI, bridge design and analysis
Xingwei Wang	Xingwei_Wang@uml.edu	Electrical and Computer Engineering	Co-PI, development of optical sensors
Zhu Mao	Zhu_Mao@uml.edu	Mechanical Engineering	Co-PI, dynamic health monitoring using motion videos
William Davids	William.Davids@maine.edu	Civil and Environmental Engineering	Co-PI, design and analysis of composite bridges
Ehsan Ghazanfari	Ehsan.Ghazanfari@uvm.edu	Civil and Environmental Engineering	Co-PI, data fusion and analysis

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
Harsh Gandhi		Ph.D.	Civil and Environmental Engineering	Manufacturing of laboratory specimens, data analysis and signal processing
Andrew Schanck		Ph.D.	Civil and Environmental Engineering	Finite element model construction and simulation
Rui Wu		Ph.D.	Electrical and Computer Engineering	Manufacturing and testing of optical sensors
Celso Do Cabo		Ph.D.	Mechanical Engineering	Assistance in the preparation for bridge field tests
Lidan Cao		Ph.D.	Electrical and Computer Engineering	Manufacturing and testing of optical sensors
Andres Biondi Vaccarriello		Ph.D.	Electrical and Computer Engineering	Manufacturing and testing of optical sensors

Table 7: Research Project Collaborators during the reporting period		
Organization	**Location**	**Contribution to the Project**

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		Financial Support	In-Kind Support	Facilities	Collaborative Research	Personnel Exchanges
AIT bridges	Brewer, Maine		X	X	X	X
Saint-Gobain North America	Northborough, Massachusetts		X	X	X	X
MaineDOT	Maine	X		X	X	X
Geophysical Suevry Systems Inc. (GSSI)	Nashua, New Hampshire				X	X

Currently, we are working with our industry partner Saint-Gobain North America (Camila Garces, Balaji Gopalan, Jackson Ivey) on identifying and developing sensing textile for another bridge in Maine or Connecticut or Massachusetts. Meanwhile, we continue working with AIT Bridges (Ken Sweeny) and Maine DOT (Dale Peabody) on finding the next candidate bridge for instrumentation. Furthermore, we also take the opportunity to develop a collaboration with a radar company (GSSI) in Nashua, New Hampshire on data analysis and potential field tests.

Changes:

1) Since February 2021, Massachusetts has started the vaccination against the covid-19 virus. Until March 22, more than one million residents have been vaccinated. The Massachusetts state government has been gradually releasing restrictions on public gathering and interstate travels. As of March 22, travelers a) returning to Massachusetts for being out of state and b) entering Massachusetts for fewer than 24 hours are exempt from 10-day quarantine. We envision that more covid-19 restrictions will be released in the near future.
2) Since Feb. 1, UML has increased our on-campus population while expanding weekly surveillance testing program. Most classes are conducted in a virtual environment. But the plan to resume face-to-face classes has been initially set to be Fall 2021.

Planned Activities:

We plan to return to the Grist Mill Bridge in different weather conditions (e.g., spring or summer) to collect the baseline data at different temperatures. We also plan to install sensing textiles on a different bridge in New England.

Task 3: Establishment and modal calibration of baseline measurements using fiber optic, video motion, and electromagnetic sensors
Task 6: Monitoring of structural performance under service and environmental loads
Task 7: Data fusion, visualization, and interpretation
Task 8: Documentation, reporting, and dissemination