Quarterly Progress and Performance Indicators Report:

Project Number and Title: C.11 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): Xingwei Wang (UML), Susan Faraji (UML), Ehsan Ghazanfari (UVM), Bill Davids (UMaine)

Reporting Period: 7/1/2022~9/31/2022

Submission Date: 9/31/2022

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 (BOTDA), optical, and electromagnetic (GPR) sensors. In the reporting quarter of this project, we identified another highway bridge in Methuen, MA for instrumentation and designed a distributed sensing system (Task 9, Year 2). We are planning on installing the sensing system now (Task 11, Year 2). We also planned to visit Grist Mill Bridge (Hampden, ME) for our annual data collection in October 2022. Our processed data are presented in this quarterly progress report.

Meeting the Overarching Goals of the Project:

- With the assistance of MassDOT, we have identified another highway bridge for instrumentation.

Accomplishments:

- We have designed and manufactured another system-level distributed sensing textiles for the long-term bridge health monitoring of a highway bridge in Massachusetts.

Task, Milestone, and Budget Progress:

Table 1: Task Progress			
Task Number: Title	**Start Date**	**End Date**	**% Complete**
Task 1 (Y1): Development of a finite element model of a composite/concrete bridge for strain range and distribution	01/01/20	02/28/20	100%
Task 2 (Y1): Design of a distributed sensing system using strain and temperature	01/01/20	03/31/20	100%
Task 3 (Y1): Establishment and modal calibration of baseline measurements using fiber optic, video motion, and electromagnetic sensors	01/01/20	07/31/20	100%
Task 4 (Y1): Installation of distributed fiber optic cables on a composite/concrete bridge	07/31/20	08/15/20	100%
Task 5 (Y1): Structural loading test and data collection	08/15/20	08/20/20	100%
Task 6 (Y1): Monitoring of structural performance under service and environmental loads	08/20/20	12/31/21	100%

Task 7 (Y1): Data fusion, visualization, and interpretation	01/01/20	12/31/21	100%
Task 8 (Y1): Documentation, reporting, and dissemination	01/01/20	12/31/21	100%
Task 9 (Y2): Design of a distributed sensing system using strain and temperature	06/01/22	12/31/22	45%
Task 10 (Y2): Establishment and modal calibration of baseline measurements using fiber optic, laser Doppler vibrometry, and electromagnetic sensors	06/01/22	07/31/22	0%
Task 11 (Y2): Installation of distributed fiber optic cables on a composite/concrete bridge	06/01/22	09/31/22	0%
Task 12 (Y2): Structural loading test and data collection	06/01/22	08/31/22	0%
Task 13 (Y2): Monitoring of structural performance under service and environmental loads	06/01/22	09/31/23	0%
Task 14 (Y2): Data fusion, visualization, and interpretation	06/01/22	12/31/23	0%
Task 15 (Y2): Documentation, reporting, and dissemination	06/01/22	12/31/23	15%

Table 2: Milestone Progress

Milestone #: Description	Corresponding Deliverable	Start Date	End Date
Milestone 1: Design and manufacturing of distributed sensing system	Experimentation design of distributed sensors for selected bridges; Quarterly report on 09/31/22	06/01/22	07/31/22
Milestone 2: Installation of distributed sensing system	Installed distributed sensors on selected bridges; Quarterly report on 09/31/22	06/01/22	08/31/22
Milestone 3: Development of baseline model for each new bridge	Baseline data for selected bridges; Quarterly reports during 09/31/22~06/30/23	06/01/22	09/01/22~05/01/23
Milestone 4: Development of graphic user interface (GUI) tool for each bridge	GUI and sensor database; Quarterly reports on 09/31/22 and 12/31/22	06/01/22	12/31/22
Milestone 5: Development of annual monitoring dataset	Sensor datasets; Quarterly reports on 09/31/23	06/01/22	08/31/23
Milestone 6: Development of structural performance curve for each bridge	Bridge performance datasets; Quarterly report on 12/31/23	06/01/22	11/31/23

Table 3: Budget Progress

Project Budget	Spend – Project to Date	% Project to Date (include the date)
$44,663.63 (Y1) (federal)	$44,663.63 (Y1) (federal)	$100 (Y1) (federal)

Is your Research Project Applied or Advanced?

☒ **Applied** (*The systematic study to gain knowledge or understanding necessary for determining the means by which a recognized and specific need may be met.)*

☐ **Advanced** *(An intermediate research effort between basic research and applied research. This study bridges basic (study to understand fundamental aspects of phenomena without specific applications in mind) and applied research and includes transformative change rather than incremental advances. The investigation into the use of basic research results to an area of application without a specific problem to resolve.)*

Education and Workforce Development:

1. Did you provide any workforce development or training opportunities to transportation professionals (already in the field)? If so, what was the training? When was it offered? How many people attended?
   N/A
2. Did you hold meetings with any transportation industry organizations or DOTs? If so, what was the meeting's purpose? When was it offered? How many people attended?
   Yes. We met our project champion Greg from MassDOT on September 13, 2022 to explain our instrumentation plan and received the support from MassDOT. Three PIs and one MassDOT engineer (Greg) attended this online meeting.

3. Did you host/participant in any K-12 education outreach activities? If so, what was the activity? What was the target age/grade level of the participants? How many students/teachers attended? When was the activity held?
   N/A

Technology Transfer:

Table 4: Presentations at Conferences, Workshops, Seminars, and Other Events					
Type	**Title**	**Citation**	**Event & Intended Audience**	**Location**	**Date(s)**

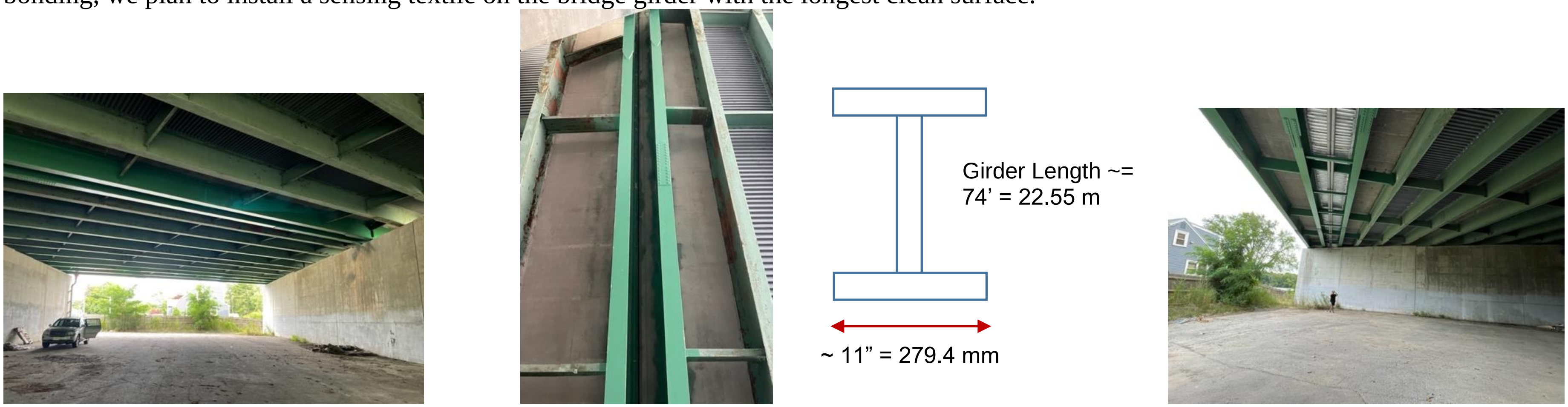
Table 5: Submitted/Accepted Publications, Technical Reports, Theses, Dissertations, Papers, and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
Peer-reviewed journal	Bridge monitoring using sensing textiles	BSCE Civil Engineering Practice	September 31, 2022	Under preparation

Answer the following questions (N/A if there is nothing to report):

1. Did you deploy any technology during the reporting period through pilot or demonstration studies as a result of this work? If so, what was the technology? When was it deployed?
   N/A
2. Was any technology adopted by industry or transportation agencies as a result of this work? If so, what was the technology? When was is adopted? Who adopted the technology?
   N/A

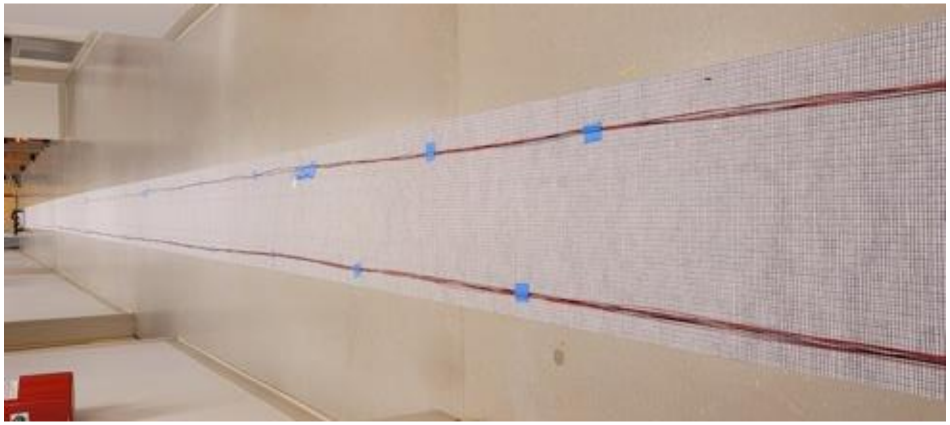
3. Did findings from this research project result in changing industry or transportation agency practices, decision making, or policies? If so, what was the change? When was the change implemented? Who adopted the change?
   N/A
4. Were any licenses granted to industry as a result of findings from this work? If so, when? To whom was the license granted?
   N/A
5. Were any patent applications submitted as a result of findings from this research? If so, please provide a copy of the patent application with your report.
   N/A
6. Did industry organizations or DOTs provide cost-share (cash or in-kind) to your research during the reporting period? Who was the organization? Please provide an in-kind support invoice from the organization with your report (this is kept confidential and used for record keeping purposes only).
   N/A

On July 27th, 2022, we surveyed the I-93 highway bridge in Methuen, MA and identified several candidate bridge girders for instrumentation. Figure 1 shows the bridge span we plan to use for instrumenting sensing textiles. One girder with a longest, clean surface (without any connections or joints) was selected. In Figure 1 b), the left bridge girder surface shows a long clean surface, while the right girder surface has a gusset plate on it. The maximum length of the clean surface is measured to be 74 ft. To ensure the installation quality and durability of epoxy bonding, we plan to install a sensing textile on the bridge girder with the longest clean surface.

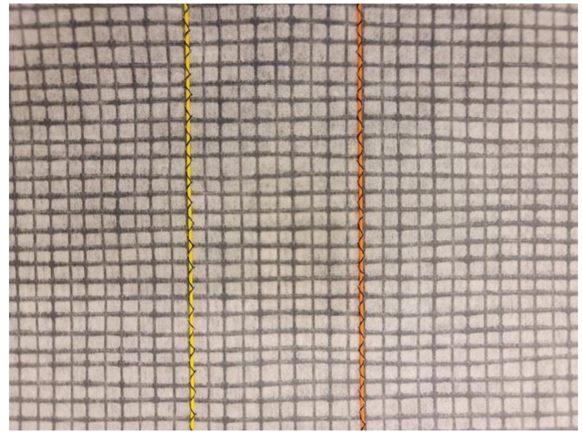


(a) I-93 highway bridge, Methuen, MA (7/27/22). (b) Bridge girders. (c) Cross sectional properties. (d) Vertical clearance under the bridge.

Fig. 1. I-93 highway bridge (Methuen, MA)



(a) Preliminary design of sensing textile



(b) Two different optical fibers used in the design.

Fig. 2. Proposed sensing textile design

In this design, we plan to use different optical fibers for both static and dynamic sensing with better signal-to-noise ratios. Figure 2 shows our preliminary design of the sensing textiles to be used for the I-93 highway bridge instrumentation.

<u>Outputs:</u>

- Distributed strain measurements using BOTDA of bridge girders are fitted with a numerical model.

<u>Outcomes:</u>

- Global property of the Grist Mill Bridge is extracted from curve-fitting result. The load vs. flexural rigidity ratio (*EI/w*) of the bridge can be used to indicate bridge health for long-term monitoring.

<u>Impacts:</u>

- Our research work has been disseminated in the annual conference held by MassDOT.

<u>Participants and Collaborators:</u>

Table 6: Active Principal Investigators, faculty, administrators, and Management Team Members

Individual Name & Title	Dates involved	Email Address	Department	Role in Research
Tzuyang Yu	4/1/2022 ~ 9/31/2022	Tzuyang_Yu@uml.edu	Civil and Environmental Eng.	Project principle investigator and Institutional Lead at UML; overseeing all project activities and working on GPR imaging and LDV sensing

Xingwei Wang	4/1/2022 ~ 9/31/2022	Xingwei_Wang@uml.edu	Civil and Environmental Eng.	Co-PI; working on optical fiber sensing
Susan Faraji	4/1/2022 ~ 9/31/2022	Susan_Faraji@uml.edu	Civil and Environmental Eng.	Co-PI; working on structural analysis
Ehsan Ghazanfari	4/1/2022 ~ 9/31/2022	Ehsan.Ghazanfari@uvm.edu	Civil and Environmental Eng.	Co-PI; working on data fusion and numerical modeling
Bill Davids	4/1/2022 ~ 9/31/2022	William.Davids@maine.edu	Civil and Environmental Eng.	Co-PI; working on structural design and finite element modeling and strain sensing

Table 7: Student Participants during the reporting period

Student Name	Start Date	End Date	Advisor	Email Address	Level	Major	Funding Source	Role in research
Koosha Raisi	4/1/22	9/31/22	Prof. Yu		Ph.D.	Civil and Environmental Engineering	TIDC	Data processing and analysis
Andres Biondi Vaccarriello	4/1/22	9/31/22	Prof. Wang		Ph.D.	Electrical and Computer Engineering	TIDC	Optical fiber data collection and processing
Rui Wu	4/1/22	9/31/22	Prof. Wang		Ph.D.	Electrical and Computer Engineering	TIDC	Optical fiber data collection and processing
Andrew Schanck	4/1/22	9/31/22	Prof. Davids		Ph.D.	Civil and Environmental Engineering	TIDC	Structural analysis and numerical modeling
Harsh Gandhi	4/1/22	9/31/22	Prof. Faraji		Ph.D.	Civil and Environmental Engineering	TIDC	Instrumentation and data collection
Guiqiang Cui	4/1/22	9/31/22	Prof. Wang		Ph.D.	Electrical and Computer Engineering	TIDC	Optical fiber data collection and processing

Table 8: Students who Graduated During the Reporting Period

Student Name	Degree/Certificate Earned	Graduation/Certification Date	Did the student enter the transportation field or continue another degree at your university?

Table 9: Industrial Internships			
Student Name	**Degree/Certificate Earned**	**Graduation/Certification Date**	**Did the student enter the transportation field or continue another degree at your university?**

Table 10: Research Project Collaborators during the reporting period						
Organization	**Location**	**Contribution to the Project**				
		Financial Support	**In-Kind Support**	**Facilities**	**Collaborative Research**	**Personnel Exchanges**
AIT bridges	Brewer, ME				X	X
Saint-Gobain North America	Northborough, MA			X	X	X
MaineDOT	Augusta, ME			X	X	X
Geophysical Survey Systems Inc. (GSSI)	Nashua, NH				X	X
MassDOT	Boston, MA		X	X	X	X

Table 11: Other Collaborators				
Collaborator Name and Title	**Contact Information**	**Organization and Department**	**Date(s) Involved**	**Contribution to Research**
Gregory Krikoris		MassDOT	9/13/22	Technical champion

Table 12: Course List						
Course Code	**Course Title**	**Level**	**University**	**Professor**	**Semester**	**# of Students**

<u>Changes:</u>

<u>Planned Activities:</u>
In the next reporting period, we plan to continue research tasks (Task 9~Task 15) in Year 2.