Final 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
PI: Tzuyang Yu (UML)
Co-PI(s): Susan Faraji (UML), Xingwei Wang (UML), Zhu Mao (UML), Bill Davids (UMaine), Ehsan Ghazanfari (UVM)
Reporting Period: 04/01/2020~09/30/2025
Date: 09/30/2025

******IMPORTANT: Please fill out each section fully and reply with N/A for questions/sections with nothing to report. For ease of reporting to the USDOT, please do not remove, or change the order of, any sections/text. You may remove/add each row in tables as needed. Thank you! ******
The report is due on the last day of the reporting period in .doc format to tidc@maine.edu.

Summary of the project:
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.

- We instrumented a composite bridge (Grist Mill Bridge in Hampden, ME) with sensing textiles.
- We have developed structural health monitoring algorithms to process the experimental measurement collected from Grist Mill Bridge (Hampden, ME) to study the long-term bridge monitoring problem.
- We have developed bridge models for extracting the flexural rigidity (EI) of the bridge. We will use it as one of the indicators for long-term health monitoring.
- We developed a bound approach to determine the structural properties of bridges by using single-point optical measurement.

Overview:

- We have collected another complete baseline dataset on the Grist Mill Bridge (Hampden, ME) using fiber optic, optical, and electromagnetic sensors during 2020~2025.
- Distributed strain measurements using BOTDA of bridge girders are fitted with a numerical model for structural health.
- We are preparing another journal paper manuscript for our experimental result on Grist Mill Bridge.
- We have demonstrated the capability of our system-level sensing technique on extracting one global property (*w/EI*) of the bridge for long-term bridge health monitoring.
- We analyzed the LDV data of a bridge under traffic loading by using the mid-span vibration of a steel bridge in Rollinsford, NH.

Meeting the Overarching Goals of the Project:
How did the previous items help you achieve the project goals and objectives? Please give one bullet point for each bullet point listed above.

- We collected a complete baseline dataset on the Grist Mill Bridge (Hampden, ME) using fiber optic, optical (laser), and electromagnetic sensors in 2020.
- We collected a baseline dataset on the Grist Mill Bridge (Hampden, ME) using fiber optic and laser sensors in 2021.

- We collected a baseline dataset on the Grist Mill Bridge (Hampden, ME) using fiber optic sensors during 2022 ~ 2025.
- With the collected sensor data, we have extracted the load vs. flexural rigidity ratio (*w/EI*) of the bridge.

Accomplishments:

- A bridge instrumentation method to extract structural properties (modal mass, modal damping, and modal stiffness) has been developed.
- New baseline dataset has been collected from Grist Mill Bridge, approximately after one year of sensor instrumentation (11/06/20) and bridge installation (12/30/20).
- Development of a long-term six-year baseline database of a composite bridge's structural behavior.

Task, Milestone, and Budget Progress:

Complete the following tables to document the work toward each task and budget (add rows/remove rows as needed, make sure you complete the Overall Project progress row and include all tasks even if they have ended or have not been started).

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	100%
Task 10 (Y2): Establishment and modal calibration of baseline measurements using fiber optic, laser Doppler vibrometry, and electromagnetic sensors	06/01/22	07/31/23	100%
Task 11 (Y2): Installation of distributed fiber optic cables on a composite/concrete bridge	06/01/22	09/31/22	100%
Task 12 (Y2): Structural loading test and data collection	06/01/22	07/31/25	100%
Task 13 (Y2): Monitoring of structural performance under service and environmental loads	06/01/22	08/31/25	100%
Task 14 (Y2): Data fusion, visualization, and interpretation	06/01/22	07/31/25	100%
Task 15 (Y2): Documentation, reporting, and dissemination	06/01/22	07/31/25	100%

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 07/31/25	06/01/22	07/31/25
Milestone 5: Development of annual monitoring dataset	Sensor datasets; Quarterly reports on 07/31/25	06/01/22	07/31/25
Milestone 6: Development of structural performance curve for each bridge	Bridge performance datasets; Quarterly report on 07/31/25	06/01/22	07/31/25

Match part expenditure:

Table 3: Budget Progress

Project Budget	Spend – Project to Date	% Project to Date (include the date)
$144,957.95 (Y1~Y3) (federal)	$144,957.95 (Y1~Y3) (federal)	100% (Y1~Y3) (federal)

Include the date the budget is current to.

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:

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

- 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? (i.e. The research team provided an in the field training for the SAR technology for 3 maintenance crew members of the , on 3/31/2021. The members learned how to use the technology and interrupt the data.)
  - N/A

- 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? (i.e. The research team held a meeting with MaineDOT to update them on the progress of the research findings and how the findings can be implemented on 3/31/2021. 15 DOT maintenance members were present at the meeting.)

- Yes. We met our project champion Greg from MassDOT on October 21, 2022 to explain our instrumentation plan and received the support from MassDOT.

- 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? (i.e. 25 8th graders and 2 teachers visited the concrete lab and created small concrete trinkets like Legos on 3/31/2021. They learned about the different types of fibers that can be used in the concrete.)
  - Yes. On three different dates (11/12/24, 11/16/24, and 11/19/24) for the visits of Chelmsford High School students at the senior year. There were nine students and one teacher on 11/12, twenty-six students and three teachers on 11/16, and eight students and one teacher on 11/19. In total, there were 43 students and 5 teachers in these visits. These visits were held in the NDT/SHM Lab in Southwick Hall Room 130.

Technology Transfer:

Complete all of the tables below and provide additional information where requested. Please provide ALL requested information as this is one of the most important sections for reporting to the USDOT. ***ONLY provide information relevant to this reporting period.***

Use the table below to complete information about conference sessions, workshops, webinars, seminars, or other events you led/attended where you shared findings as a result of the work you conducted on this project:

Table 4: Presentations at Conferences, Workshops, Seminars, and Other Events					
Type	**Title**	**Citation**	**Event & Intended Audience**	**Location**	**Date(s)**
Conference presentation	Optical fiber sensing textile for temperature and strain distributed measurement	Proceedings Volume 11592, Nondestructive Characterization and Monitoring of Advanced Materials, Aerospace, Civil Infrastructure, and Transportation XV; 115921G (2021) https://doi.org/10.1117/12.2595377 Event: SPIE Smart Structures + Nondestructive Evaluation, 2021, Online Only	Conference presentation, prerecorded	Virtual meeting	March 23, 2021
Conference presentation	Sensing Textiles for Bridge Health Monitoring	MassDOT Transportation Innovation Conference	MassDOT annual conference / state DOT engineers, contractors, researchers, students (>50)	Worcester, MA	May 25, 2022
Presentation	A Bound Approach to Estimate Structural	Tzuyang Yu, invited seminar talk, Department of Civil Engineering, National Cheng-Kung University (NCKU)	Faculty and graduate students	Tainan, Taiwan	October 24, 2024

	Properties from LDV Measurement				
Presentation	Remote Sensing Techniques for Surface and Subsurface Condition Assessment using Laser Doppler Vibrometry and Synthetic Aperture Radar	Tzuyang Yu, invited seminar talk, Department of Civil Engineering, National Taiwan University (NTU)	Faculty and graduate students	Taipei, Taiwan	October 25, 2024
Conference presentation	Remote inspection of a steel railway bridge using laser Doppler vibrometry and a bound approach	SPIE Smart Structures/Nondestructive Evaluation (SS/NDE) Symposium	International conference / academia (faculty and students), government industry	Vancouver, Canada	March 18, 2025

Use the table below to report any publications, technical reports, peer-reviewed articles, newspaper articles referencing your work, graduate papers, dissertations, etc. written as a result of the work you conducted on this project. Please list only completed items and exclude work in progress.

Table 5: Submitted/Accepted Publications, Technical Reports, Theses, Dissertations, Papers, and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
Conference paper	Remote inspection of a steel railway bridge using laser Doppler vibrometry and a bound approach	Tzuyang Yu, Qixang Tang, Maryam Abazarsa, SPIE Smart Structures/Nondestructive Evaluation Symposium, Proceedings Volume 13436, Nondestructive Characterization and Monitoring of Advanced Materials, Aerospace, Civil Infrastructure, and Transportation XIX; 134360J (2025) https://doi.org/10.1117/12.3051419 Event: SPIE Smart Structures + Nondestructive Evaluation, 2025, Vancouver, B.C., Canada	June 20, 2025	Published
Conference paper	Optical fiber sensing textile for temperature and strain distributed measurement	https://doi.org/10.1117/12.2595377	March 23, 2021	Published
Peer-reviewed journal	Pipeline structural health monitoring using distributed fiber optic sensing textile	*Optical Fiber Technology*, Volume 70, May 2022, 102876 / doi: 10.1016/j.yofte.2022.102876	December 20, 2021	Published

Peer-reviewed journal	Bridge monitoring using sensing textiles	BSCE Civil Engineering Practice	December 31, 2021	Published
Conference paper	Distributed optic fiber sensing textile installation inside a novel composite girder bridge	Abedin, S., A.M. Biondi Vaccariello, L. Cao, R. Wu, T. Yu, X. Wang, Real time traffic monitoring of pedestrian bridge using distributed fiber optic sensing textile, In: *Proc SPIE Smart Structures/NDE*, vol. 12487, March 15, doi:10.1117/12.2658097.	May 2, 2023	Published
Conference paper	Real time traffic monitoring of pedestrian bridge using distributed fiber optic sensing textile	Wu, R., A. M. Biondi Vaccariello, L. Cao, G. Cui, S. Abedin, X. Wang, H.N. Gandhi, T. Yu, Distributed optic fiber sensing textile installation inside a novel composite girder bridge, In: *Proc SPIE Smart Structures/NDE*, vol. 12487, March 14, doi:10.1117/12.2662371.	May 2, 2023	Published
Conference paper	Structural health monitoring (SHM) of a train model under traffic loading	Batchu, R., K. Raisi, T. Yu, Structural health monitoring (SHM) of a train model under traffic loading, In: *Proc SPIE Smart Structures/NDE*, vol. 12486, March 15, doi: 10.1117/12.2658173.	May 2, 2023	Published
Journal paper	Composite Bridge Girders Structure Health Monitoring Based on the Distributed Fiber Sensing Textile	Wu, R., A. Biondi, L. Cao, H. Gandhi, S. Abedin, G. Cui, T. Yu, X. Wang, *Sensors*, 23(10), 4856; doi.org/10.3390/s23104856	May 17, 2023	Published
Journal paper	Smart textile embedded with distributed fiber optic sensors for railway bridge long term monitoring,	Andres M. Biondi, Xu Guo, Rui Wu, Lidan Cao, Jingcheng Zhou, Qixiang Tang, **T. Yu**, Balaji Goplan, Thomas Hanna, Jackson Ivey, Xingwei Wang, *Optical Fiber Technology*, 80, 103382, doi:10.1016/j.yofte.2023.103382	June 19, 2023	Published
Conference paper	Remote Inspection of a Steel Railway Bridge using Laser Doppler Vibrometry and a Bound Approach	Tzuyang Yu, Qixang Tang, Maryam Abazarsa, SPIE Smart Structures/Nondestructive Evaluation Symposium, Proceedings Volume 13436, Nondestructive Characterization and Monitoring of Advanced Materials, Aerospace, Civil Infrastructure, and Transportation XIX; 134360J (2025) https://doi.org/10.1117/12.3051419 Event: SPIE Smart Structures +	November 12, 2024	Published

		Nondestructive Evaluation, 2025, Vancouver, B.C., Canada		
Journal paper	Instrumentation and Monitoring of a New FRP Composite Bridge using Sensing Textiles	T. Yu, S. Vinayaka, Q. Tang, R. Wu, A. Biondi Vaccarriello, X. Wang, C. Garcia, B. Gopalan, J. Ivy, T. Hanna, T. Kenerson, BSCE Civil Engineering Practice	December 11, 2024	Published
Conference paper	Remote inspection of a steel railway bridge using laser Doppler vibrometry and a bound approach	Tzuyang Yu, Qixang Tang, Maryam Abazarsa, SPIE Smart Structures/Nondestructive Evaluation Symposium	March 18, 2025	Published
Journal paper	Instrumentation and Monitoring of a New FRP Composite Bridge using Sensing Textiles	T. Yu, S. Vinayaka, Q. Tang, R. Wu, A. Biondi Vaccarriello, X. Wang, C. Garcia, B. Gopalan, J. Ivy, T. Hanna, T. Kenerson, BSCE Civil Engineering Practice, Volume 32, Issue 1	January 2025	Published

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

- 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?
  - Yes, we collected another baseline dataset from the installed optical sensors and applied an optical sensor (LDV) and an EM sensor (GPR) on Grist Mill Bridge during November 3~4, 2021.

- 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?
  - Yes. The distributed sensing textile was installed on Grist Mill Bridge (built by AIT Bridges and MaineDOT) in Hampden, ME. Commercially available GPR and LDV sensors were also applied on Grist Mill Bridge during November 3~4, 2021.

- 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?
  - Yes. MaineDOT has started constructing composite bridges to replace traditional prestressed concrete bridges.

- 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

- 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

- 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).
    - Yes. MaineDOT (Dale Peabody) provided logistic supports to the UML research team during November 3~4, 2021. We will send an invoice to MaineDOT for their support. We also received in-kind contributions from the optical industry (Luna).

Please add figures/images that can be included on the website and/or in marketing/social media materials to further clarify your research to the general public. This is very important to our Technology Transfer initiatives

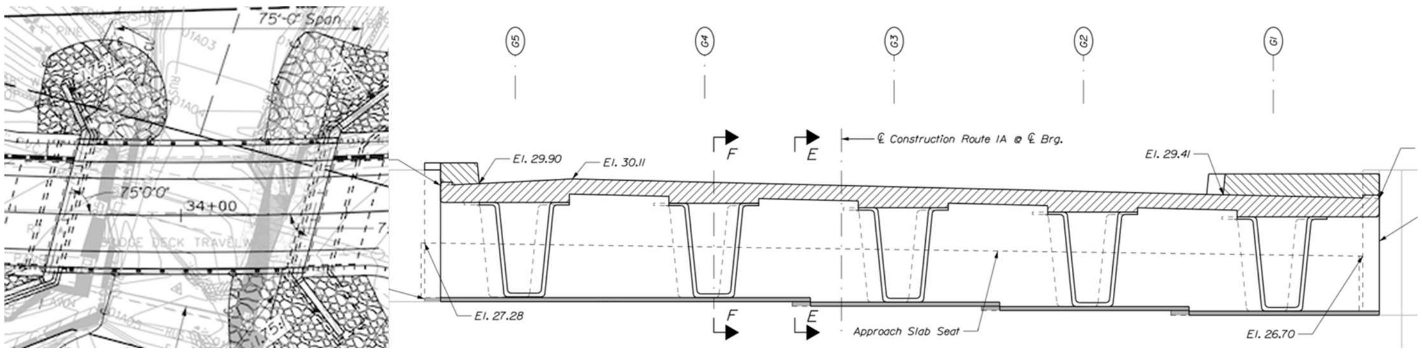


Figure 1. Layout and cross section of Grist Mill Bridge (Hampden, ME) (Source: MaineDOT)

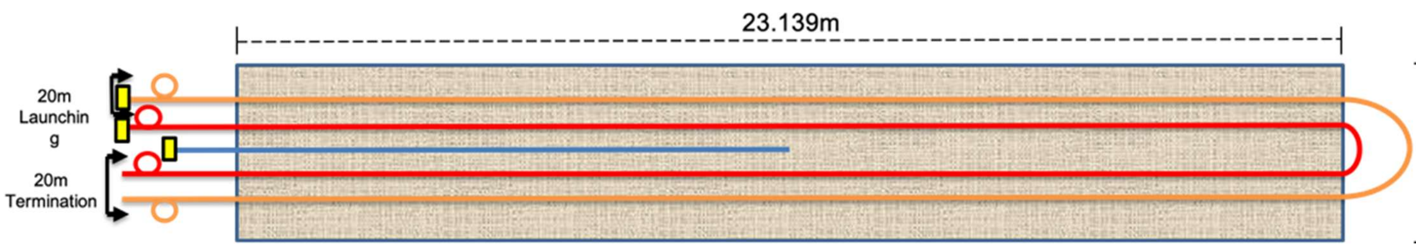


Figure 2. Design of a distributed fiber optic sensing system.

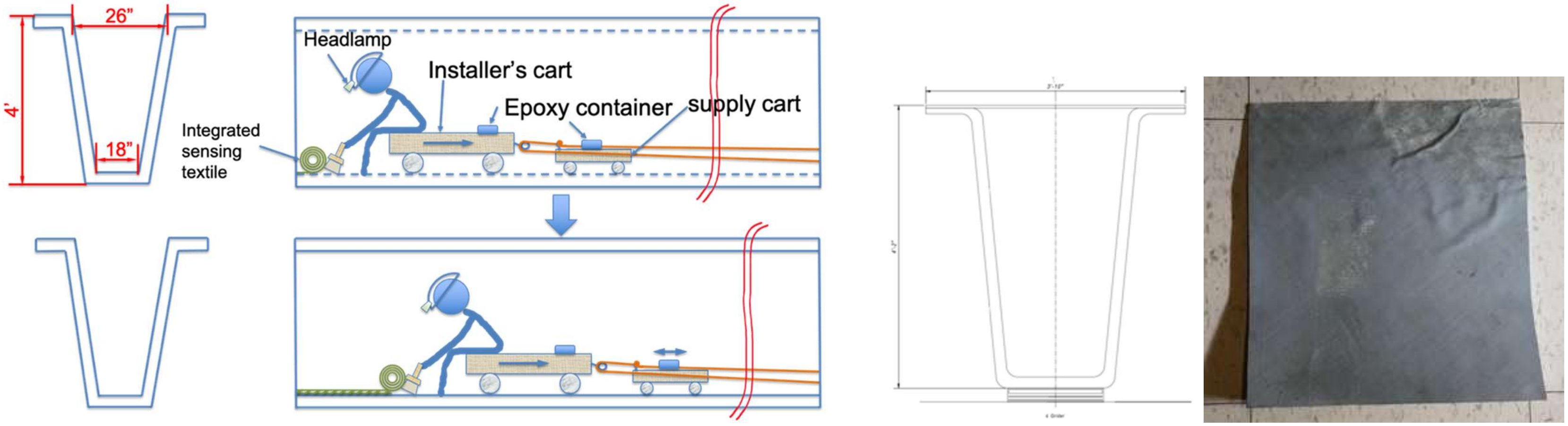


Figure 3. (a) Installation schematic (b) Detailed cross section of a composite bridge girder (Source: MaintDOT) and composite sample (by AIT Bridges)

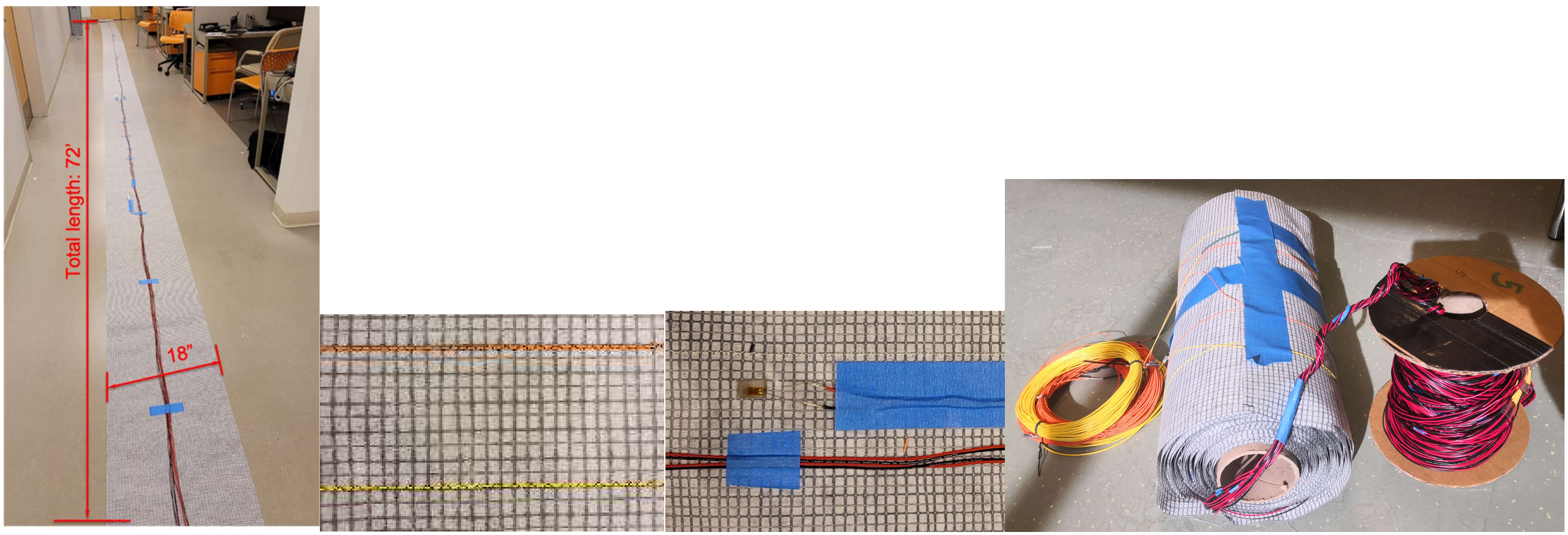


Figure 4. (a) Unfold integrated sensors (b) Sensing textile (d) Strain gauge on sensing textile (e) Rolled up integrated sensors

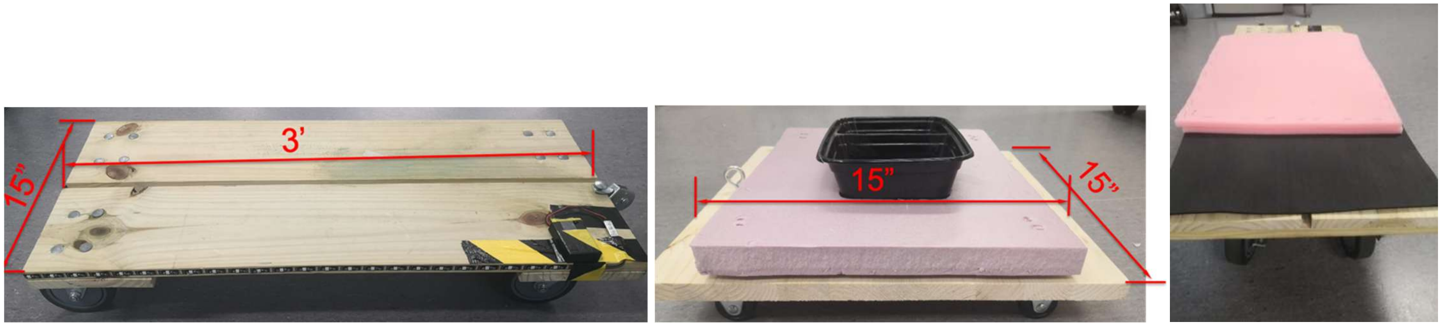


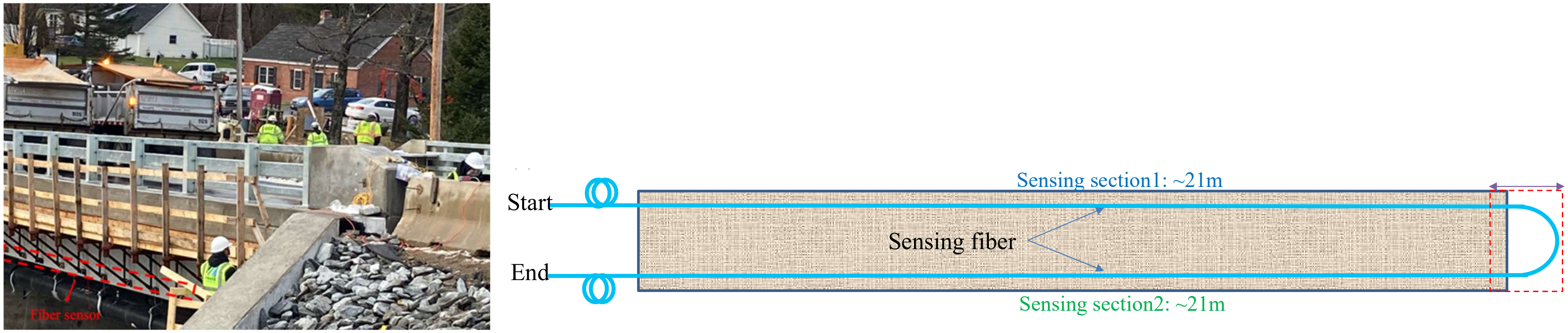
Figure 5. (a) Installer's cart (b) Supply cart for epoxy supply. (c) Mat on installer's cart

Figure 6. (a) Composite bridge girder at AIT Bridges (Brewer, ME) (b) Mock-up bridge girder at UML.

Figure 7. Installation of sensing textiles on three composite bridge girders (10/06/2020)

Figure 8. (a) Sensing textile installation scheme and (b) result (c) Design of integrated sensing textiles.

Figure 9. Baseline data collection (11/03/2020)



a) Installed optical fiber sensors b) Layout of optical fiber sensors

Figure 10. Installed optical fiber sensors on the Grist Mill Bridge

Figure 11. (a) Grad students Lidan and Rui collecting data. (b) Grad Harsh collecting data. (c) Video camera setup.

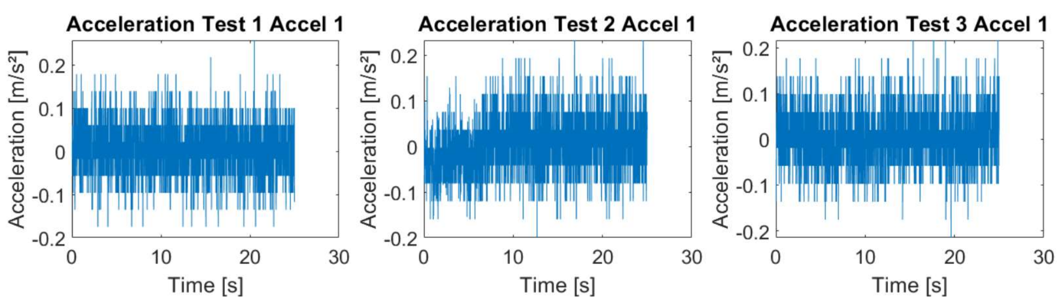


Figure 12. Raspberry Pi setup. **Figure 13.** Raspberry Pi time domain response (Y direction)

Figure 14. Grad student Celso collecting field data.

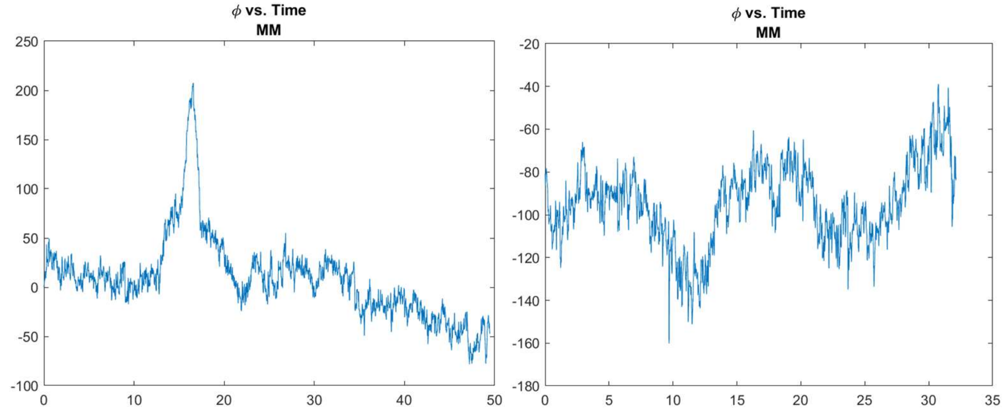


Figure 15. a) Bridge vibration at 20mph b) bridge vibration at 30mph

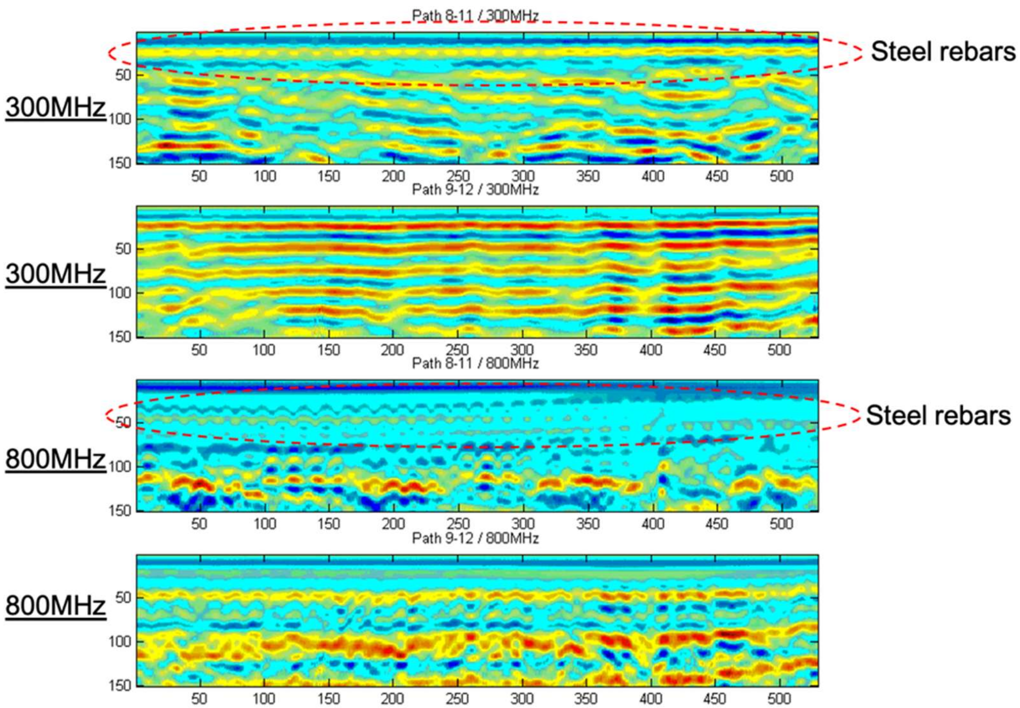


Figure 16. GPR baseline images of 300MHz and 800MHz frequencies.

Figure 17. L-15-076 Rt. 3 Bridge (Lowell)

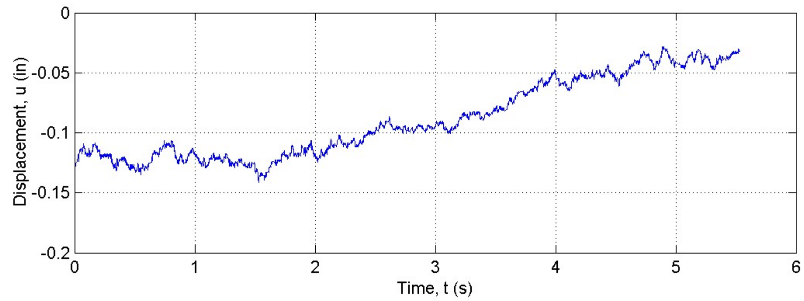
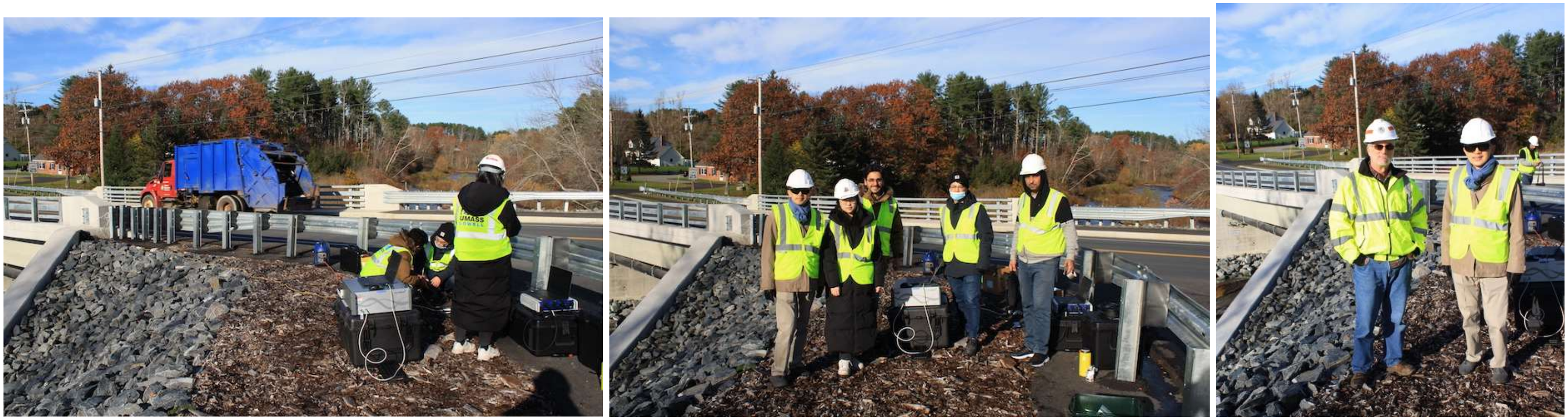


Figure 18. (a) Mid-span vibration of the bridge – 5.5 sec., displacement

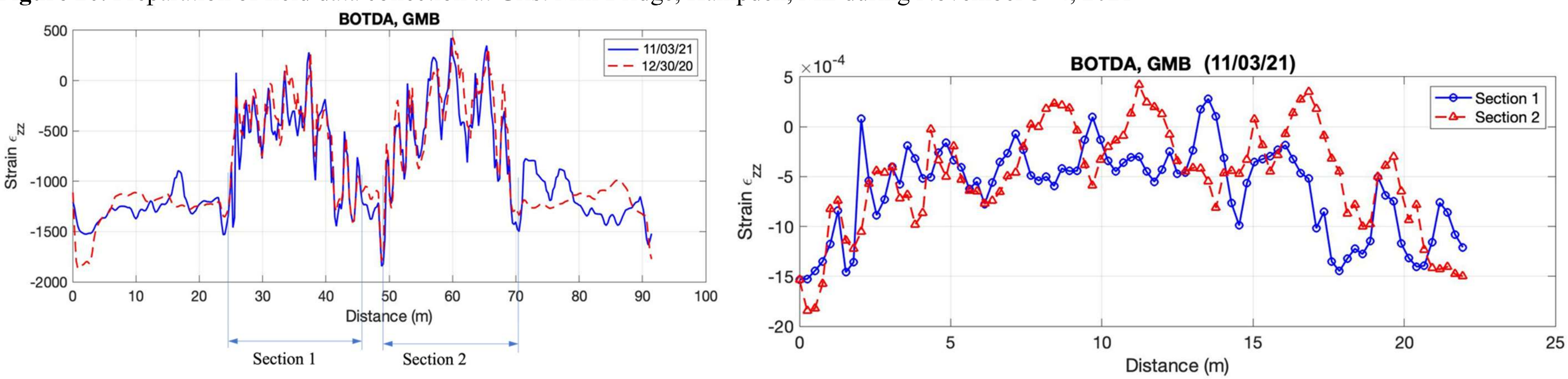
(a) Checking the condition of installed sensors. (b) Installation of an accelerometer on the bridge (c) Setup of optical sensor data collection system

Figure 19. Preparation of field data collection at Grist Mill Bridge, Hampden, ME during November 3~4, 2021



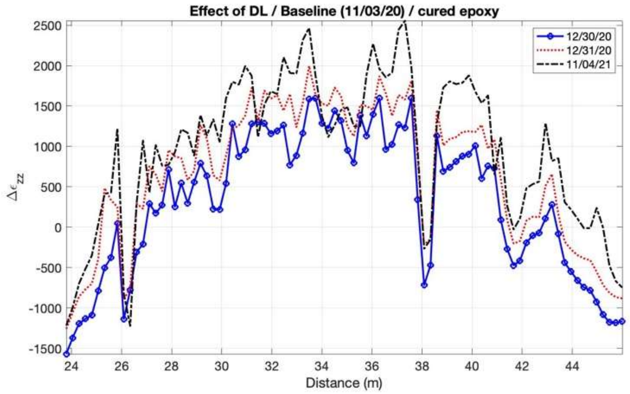
(a) Collecting loaded response of the bridge. (b) The UML research team (c) D. Peabody (MaineDOT) (left)

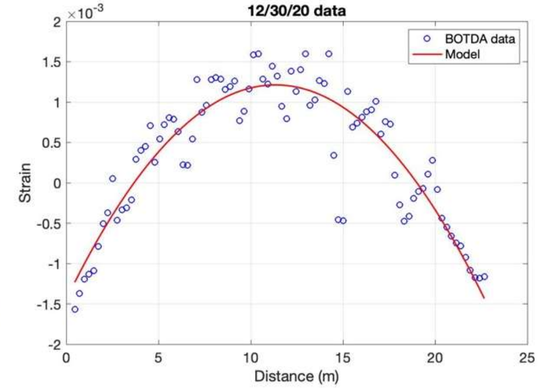
Figure 20. Preparation of field data collection at Grist Mill Bridge, Hampden, ME during November 3~4, 2021



(b) BOTDA data of Grist Mill Bridge collected on 12/30/20 and 11/03/21. (b) BOTDA data of Grist Mill Bridge collected on 11/03/21

Figure 21. BOTDA datasets collected on 12/30/20 and 11/03/21 at Grist Mill Bridge, Hampden, ME.

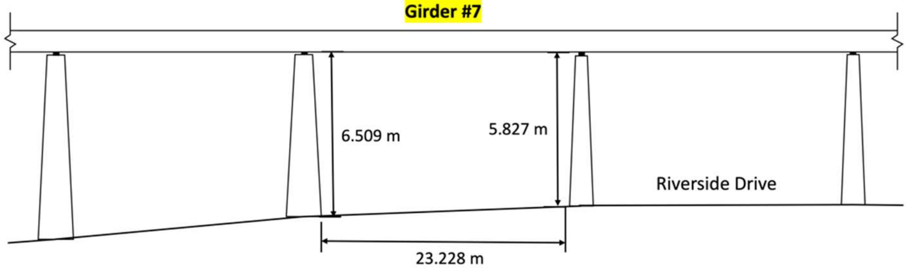


(c) Grist Mill Bridge data collection on 12/30/20. (b) Temperature-compensated BOTDA strain data. (c) Curve-fitting of BOTDA strain data.

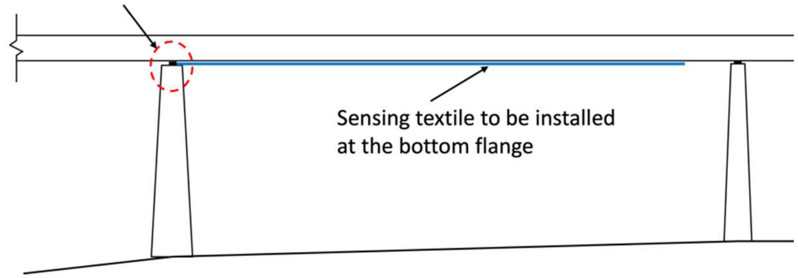
Figure 22. BOTDA strain datasets collected from the Grist Mill Bridge (Hampden, ME)


(a) I-495 highway bridge in MA. (b) Top-view of twenty-two girders of the bridge. (c) Selected steel girder.

Figure 23. Selected highway bridge in MA for long-term instrumentation.



(a) Dimensions of the bridge span.



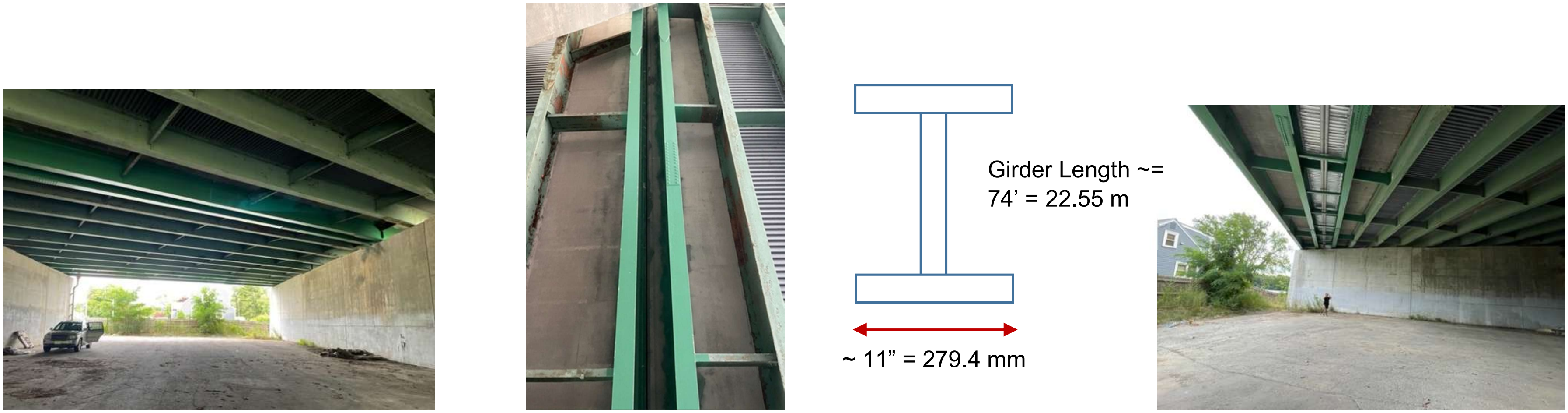
(b) Installation of sensing textile at the bottom flange of the girder.

Figure 24. Selected highway bridge in MA for long-term instrumentation.

(a) Example extension end of sensing textile (from SFR Bridge, NH).

(b) Example round end of sensing textile (from SFR Bridge, NH).

Figure 25. Example installed sensing textile from Salmon Falls River Bridge in NH.



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

Figure 26. I-93 highway bridge (Methuen, MA)

Figure 27. The UML team conducting field test at Grist Mill Bridge (2022)

Fig. 28. Visit of high school students on 11/12/24.

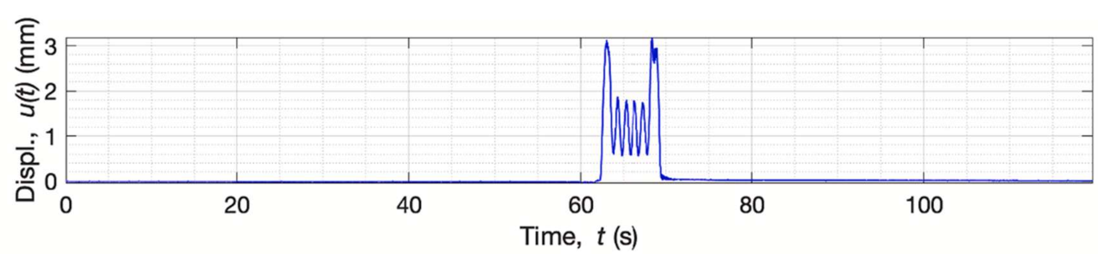
Fig. 29. Visit of high school students on 11/16/24.

Fig. 30. Visit of high school students on 11/19/24.

(a) Field data collection of LDV measurement.

(b) Portable LDV system.

Figure 31. Field LDV data collection.



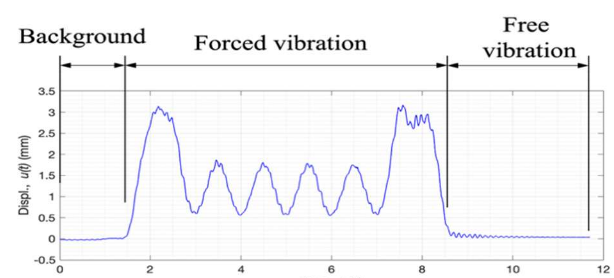
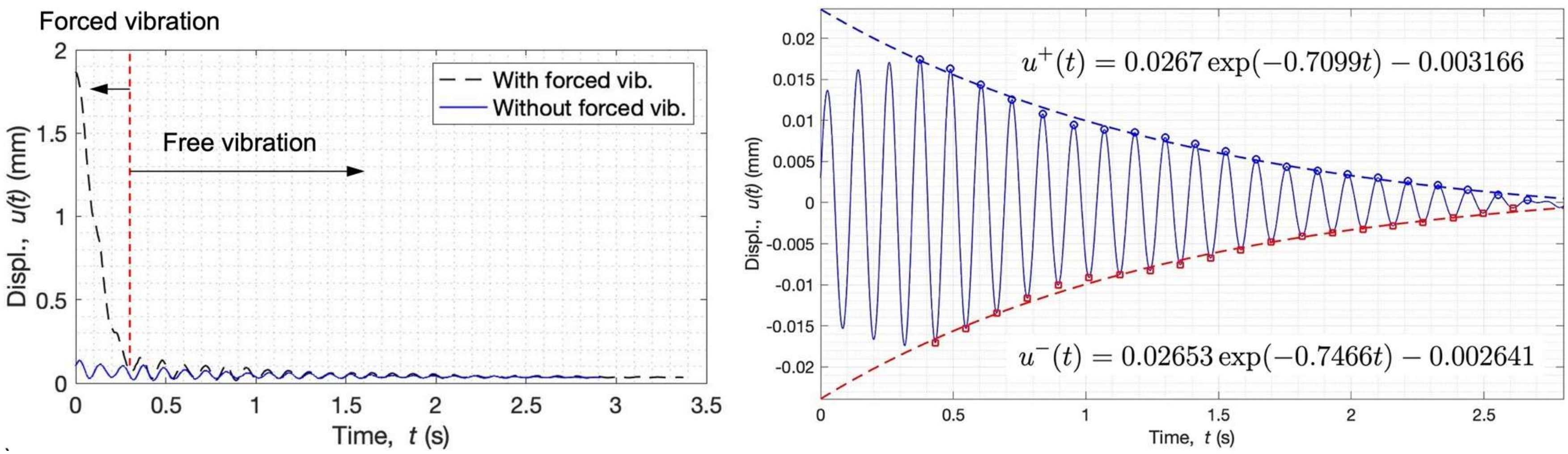


Figure 32. Traffic-induced forced and free vibration response of the bridge at mid-span.



(a) Forced and free vibration of mid-span displacement of the bridge. (b) Attenuation of free vibration at the mid-span of the bridge.

Figure 33. Forced and free vibration and the attenuation of mid-span displacement of the bridge.

Describe any additional activities involving the dissemination of research results not listed above under the following headings:

Outputs:

Definition: Any new or improved process, practice, technology, software, training aid, or other tangible product resulting from research and development activities. They are used to improve the efficiency, effectiveness, and safety of transportation systems. List any outputs accomplished during this reporting period:

- A new distributed sensing technology (hardware, software, algorithm) for bridges has been developed and applied for six years in the field for the long-term health monitoring of transportation infrastructure.
- A new single-point sensing technology (hardware, software, algorithm) for bridges has been developed using a bound approach and laser Doppler vibrometry (LDV) to estimate the structural modal properties (modal mass, modal damping, and modal stiffness).

Outcomes:

Definition: The application of outputs; any changes made to the transportation system, or its regulatory, legislative, or policy framework resulting from research and development activities. List any outcomes accomplished during this reporting period:

- Example: The developed sensing technology was installed in Bridge A in town, state on 1/1/2021. This installation will… The UAV was successfully used by ___ Organization to inspect ___ Bridge in in town, state on 1/1/2021… The newly created college course was taken/completed by __ students in the 2021 fall semester.

- Our developed distributed sensing technology (sensing textiles) was installed on Grist Mill Bridge (Hampden, ME) on 12/30/2020. Since its installation, we have been collecting baseline data on an annual basis for six consecutive years.

- Our developed LDV sensing technology has been applied on Salmon Falls River Bridge (Rollinsford, NH) during 2020~2021. Our LDV measurements successfully led to the development of a bound approach to estimate structural properties of bridges from the mid-span LDV measurement.

Impacts:

Definition: The effects of the outcomes on the transportation system such as reduced fatalities, decreased capital or operating costs, community impacts, or environmental benefits. The reported impacts from UTCs are used for the assessment of each UTC and to make a case for Federal funding of research and education by demonstrating the impacts that UTC funding has had on technology and education. NOTE: The U.S. DOT uses this information to assess how the research and education programs (a) improve the operation and safety of the transportation system; (b) increase the body of knowledge and technologies; (c) enlarge the pool of people trained to develop knowledge and utilize technologies; and (d) improves the physical, institutional, and information resources that enable people to have access to training and new technologies. List any outcomes accomplished during this reporting period:

- **Improved Transportation Safety and Monitoring**
  From the development, installation, and application of two system-level bridge sensing technologies (sensing textiles and LDV), we have developed new technologies to improve transportation safety and monitoring.

- **Contribution to Knowledge and Technology Development**
  We published our research findings in peer-reviewed journal and conference papers and contributed to the field of bridge health monitoring. Our technologies are field tested with lont-term data.

- **Education and Workforce Development**
  We hosted many K-12 students at both UML and UMaine in lab visits and open houses. We also hired undergraduate and graduate students to work on the project for both education and workforce development.

- **Enhanced Research Infrastructure**
  Our research activities encompassed various industries (fiber optics, laser, radar) and formed a special research infrastructure. Our research efforts have reinforced the collaborations among all team members.

Participants and Collaborators:

Use the table below to list individuals (compensated or not) who have worked on the project other than students.

Table 6: 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	Project principal investigator (PI) and Institutional

		Environmental Eng.	Lead at UML; overseeing all project activities and working on GPR imaging and LDV sensing
Xingwei Wang	Xingwei_Wang@uml.edu	Civil and Environmental Eng.	Co-PI; working on optical fiber sensing
Susan Faraji	Susan_Faraji@uml.edu	Civil and Environmental Eng.	Co-PI; working on structural analysis
Ehsan Ghazanfari	Ehsan.Ghazanfari@uvm.edu	Civil and Environmental Eng.	Co-PI; working on data fusion and numerical modeling
Bill Davids	William.Davids@maine.edu	Civil and Environmental Eng.	Co-PI; working on structural design and finite element modeling and strain sensing

Use the table below to list ***all*** *students who have participated in the project during the reporting period. (This includes all paid, unpaid, intern, independent study, or any other student that participated in this project.)* ***ALL FIELDS ARE REQUIRED.***

Table 7: Student Participants during the reporting period

Student Name	Start Date	End Date	Advisor	Email Address	Level	Major	Funding Source	Role in research
Maryam Abazarsa	4/1/25	6/30/25	Prof. Yu	Koosha_Raisi@ student.uml.edu	Ph.D.	Civil and Environmental Engineering	TIDC	Data processing and analysis
Rui Wu	4/1/25	6/30/25	Prof. Wang	Rui_Wu @student.uml.edu	Ph.D.	Electrical and Computer Engineering	TIDC	Optical fiber data collection and processing
Sabrina Abedin	4/1/25	6/30/25	Prof. Wang	Sabrina_Abedin@ student.uml.edu	Ph.D	Electrical and Computer Engineering	TIDC	Optical fiber data collection and processing
Guoqiang Cui	4/1/25	6/30/25	Prof. Wang	Guoqiang_Cui@ student.uml.edu	Ph.D	Electrical and Computer Engineering	TIDC	Optical fiber data collection and processing
Sanjana Vinayaka	4/1/22	6/30/22	Prof. Yu	Sanjana_Vinayaka @student.uml.edu	Ph.D.	Civil and Environmental Engineering	TIDC	Manufacturing of laboratory specimens, field radar imaging of structures, data analysis and signal processing

Jianing Wang	4/1/22	6/30/22	Prof. Yu	Jianing_Wang@student.uml.edu	Ph.D.	Civil and Environmental Engineering	TIDC	Manufacturing of laboratory specimens, field radar imaging of structures, data analysis and signal processing
Ronan Bates	4/1/22	6/30/22	Prof. Yu	Ronan_Bates @student.uml.edu	B.S.	Civil and Environmental Engineering	TIDC	Assistance in the preparation for bridge field tests
Nasharie Peralta	4/1/22	6/30/22	Prof. Wang	Nasharie_Peralta @student.uml.edu	B.S.	Civil and Environmental Engineering	TIDC	Assistance in the preparation for bridge field tests
BiondiVaccariello, Andres M	4/1/22	6/30/22	Prof. Wang	Andres_BiondiVaccariello@student.uml.edu	Ph.D.	Electrical and Computer Engineering	TIDC	Optical Fiber sensor design
Andrew Schanck	4/1/22	6/30/22	Prof. Wang	Andrew.Schanck@maine.edu	Ph.D.	Civil and Environmental Engineering	TIDC	Finite element model construction and simulation
Lidan Cao	4/1/22	9/30/25	Prof. Wang	Lidan_cao@student.uml.edu	Ph.D.	Electrical and Computer Engineering	TIDC	Preliminary data output format analysis
Sophe Ying	7/1/21	9/30/21	Prof. Yu	Sophe_Ying@ student.uml.edu	B.S.	Civil and Environmental Engineering	TIDC	Assistance in the preparation for bridge field tests
Yaneliz Garcis Ruiz	7/1/21	9/30/21	Prof. Yu	Yaneliz_Garciaruiz@ @student.uml.edu	B.S.	Civil and Environmental Engineering	TIDC	Assistance in the preparation for bridge field tests

Tiana Robinson	7/1/21	9/30/21	Prof. Yu	Tiana_Robin@ student.uml.edu	B.S.	Civil and Environmental Engineering	TIDC	Assistance in the preparation for bridge field tests

Use the table below to list any students who worked on this project and graduated or received a certificate during this reporting period. Include information about the student's accepted employment during the reporting period (i.e. the student is now working at MaineDOT) or if they are continuing their students through an advanced degree (list the degree and where they are attending).

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?
Nimun Nak Khun	Masters degree	May 23, 2022	Yes

Use the table below to list any students that participated in Industrial Internships during the reporting period:

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?

*Use the table below to list **organizations** that have been involved as partners on this project and their contribution to the project during the reporting period.*

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
Maine Department of Transportation (MaineDOT)	Augusta, Maine				X	X
AIT Bridges	Brewer, Maine		X	X	X	X
MaineDOT	Maine	X		X	X	X
MassDOT	Boston		X	X	X	X
Luna Innovations	Roanoke, VA		X		X	X

*Use the table below to list **individuals** that have been involved as partners on this project and their contribution to the project during the reporting period.*

(List your technical champion(s) in this table. *This also includes collaborations within the lead or partner universities who are not already listed as PIs; especially interdepartmental or interdisciplinary collaborations.)*

Table 11: Other Collaborators				
Collaborator Name and Title	**Contact Information**	**Organization and Department**	**Date(s) Involved**	**Contribution to Research**
Gregory Krikoris	Gregory.Krikoris@state.ma.us	MassDOT	07/16/24	Technical champion

Number of active industrial partners involved in this research project
One

Number of technical Champions actively involved in this project:
One

Use the following table to list any transportation related course that were taught or led by researchers associated with this research project during the reporting period:

Table 12: Course List						
Course Code	**Course Title**	**Level**	**University**	**Professor**	**Semester**	**# of Students**
ENGN.2070-201	Dynamics	Sophomore	UML	Tzuyang Yu	Spring 2025	21
CIVE 5570	Structural Dynamics	Grad	UML	Tzuyang Yu	Fall 2021	18
ENGN 2050	Statics	Undergrad	UML	Tzuyang Yu	Fall 2021	41
CIVE 5110	Inspection and Monitoring of Civil Infrastructure	Grad	UML	Tzuyang Yu	Spring 2022	17
ENGN 2070	Dynamics	Undergrad	UML	Tzuyang Yu	Spring 2022	37
ENGN 2070-201	Dynamics	Sophomore	UML	Tzuyang Yu	Spring 2023	38
ENGN 2070-202	Dynamics	Sophomore	UML	Tzuyang Yu	Fall 2024	32
ENGN.2070-201	Dynamics	Sophomore	UML	Tzuyang Yu	Spring 2025	21
CIVE.5110	Inspection and Monitoring of Civil Infrastructure	Grad	UML	Tzuyang Yu	Fall 2025	21
ENGN.2070-201	Dynamics	Sophomore	UML	Tzuyang Yu	Fall 2025	50

Changes:

List any actual or anticipated problems or delays and actions or plans to resolve them (list no-cost extension requests here)…
N/A

List any changes in approach and the reasons for the change…
N/A

Planned Activities:

List the activities planned during the next quarter.
N/A