Quarterly Progress and Performance Indicators Report:

Project Number and Title: Project 1.2: Condition/Health Monitoring of Railroad Bridges for Structural Safety, Integrity, and Durability
Research Area: Thrust 1 -Transportation Infrastructure Monitoring & Assessment for Enhanced Life
PI: Ramesh B. Malla, Ph.D., F. ASCE, F. EMI, Professor, Department of Civil & Environmental Engineering, University of Connecticut, and **Institutional Lead** for US DOT Region 1 UTC-TIDC Program
Co-PI(s): N/A
Reporting Period: January 01, 2022, to March 31, 2022
Submission Date: March 31, 2022

Overview:

*Provide **BRIEF** highlights of activities performed during the reporting period.*

- The velocity-time domain response obtained from the field test of Cos Cob bridge, CT (span 3), Figure 1, under service, using a Single-Point Laser Doppler Vibrometer was processed and analyzed to determine natural frequencies of vibration (vertical and lateral), and displacement (vertical and lateral).
- The acceleration-time response obtained from similar field test was analyzed to determine natural frequencies and compared with the natural frequencies determined from the Single-Point Laser Doppler Vibrometer. The comparison shows a close match.
- The natural frequencies of vibration of the Cos Cob Bridge, CT are also extracted using Finite Element Modal Analysis. The first three frequencies determined from this analytical approach are close to the ones determined from the experimental approach.
- The research team held a meeting with the Technical Champions of the project from CT DOT, Metro North Railroad and Polytec Inc. on March 28, 2022.

Meeting the Overarching Goals of the Project:

How did the previous items help you achieve the project goals and objects? Please give one bullet point for each bullet point listed above.

- Integration of velocity-time data recorded for different moving trains (Amtrak Acela, Amtrak Regional and Metro North) at different speed provides displacement-time response at a particular node. The maximum nodal displacement of the bridge can be identified from the displacement-time diagram.
- The Finite Element Modal will be used in transient analysis to simulate the response of different trains moving at different speeds.
- The nodal displacement response from the transient analysis will be compared with the nodal displacement response from the field test for a particular train moving with a particular speed for modal calibration. Once the modal is calibrated, analysis will be carried out at the speeds higher than maximum allowable speed (40 Mph) in the bridge.
- The research team presented on the methodology and the outcome of the research, and discussed on how industry can implement our methodology in the health monitoring campaign.

Accomplishments:

List any accomplishments achieved under the project goals in bullet point form…

- The velocity time-domain response obtained from the Single-Point Laser Vibrometer and the acceleration-time plot from the accelerometer has been successfully processed and analyzed to identify the natural frequencies and the nodal displacement for a particular train moving with a particular speed.
- The research team is step closer to calibrate the Finite Element Model, which will later be used in static and dynamic analysis under the train loading.

Task, Milestone, and Budget Progress:

Complete the following tables to document the work toward each task and budget

Table 1: Task Progress

Task Number: Title	Start Date	End Date	% Complete
Task 1: Literature search and review; communication with New England state DOTs for railroad bridge material collection and information/data	October 1, 2018	May 31, 2022	97%
Task 2: Existing railroad bridge material testing	January 1, 2019	May 31, 2022	80%
Task 3: Finite Element (FE) modeling of railroad bridge	June 1, 2019	May 31, 2022	95%
Task 4: Determine optimal number and locations of sensor for effective bridge condition monitoring	December 1, 2019	May 31, 2022	75%
Task 5: Determine from the analytical and FEM analysis effects of vehicle speed/type on bridge response and DMF	June 1, 2020	May 31, 2022	80%
Task 6: Prepare procedure to field test and data collection by applying a limited number of sensors to bridge, collect field data, update FE Model, and verify that sensors give sufficient info to determine condition of bridge	October 1, 2020	May 31, 2022	80%
Final Report preparation and submission	January 1, 2022	June 30, 2022	0%
Overall Project:	October 01, 2018	June 30, 2022	87%

Table 2: Milestone Progress

Milestone #: Description	Corresponding Deliverable	Start Date	End Date
Milestones will closely represent task items listed above	Quarterly and final reports	Will closely follow task dates (See Table 1 above)	Will closely follow task dates (See Table 1 above)

Table 3: Budget Progress		
Project Budget	**Spend – Project to Date**	**% Project to Date (include the date)**
Enter Phase 1 Full Budget	*Enter Phase 1 Full Spend Amount*	*Enter Phase 1 % Spent*
$498,000	$459,780	92.33%

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):

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? (i.e. The research team provided an in the field training for the SAR technology for 3 maintenance crew members of the MassDOT on 3/31/2021. The members learned how to use the technology and interrupt the data.)
    - 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? (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.)
    - Virtual meeting held on March 28, 2022 with the CT DOT, Metro-North Railroad Co., and Polytec, Inc., provide project update, discuss, and receive feedback, comments to make the project outcome as best applicable as possible to the DOTs and industry. 7 members were present.

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? (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.)
    - N/A

Technology Transfer:

Complete all of the tables below and provide additional information where requested.

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)**
i.e. Conference, Symposium, DOT/AOT presentation, Seminar, etc.	*Presentation Title*	*Full Citation*	*Name of event (i.e. TIDC 1st Annual Conference) or who was the presentation given to?*		
N/A	N/A	N/A	N/A	N/A	N/A

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**
i.*e. Peer-reviewed journal, conference paper, book, policy paper, magazine/newspaper article*	*Publication title*	*Full citation*		*i.e. Submitted, accepted, under review (by org. submitted to)*
N/A	N/A	N/A	N/A	N/A

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

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 – Cos Cob Bridge, (CT), Span 3

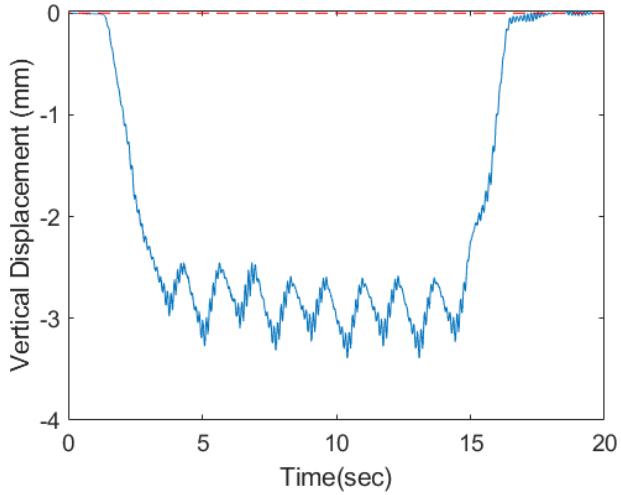

Figure 2 – Nodal Displacement (vertical) vs time diagram for Metro-North train moving at 37 Mph from New York to New haven on track 4 (Node shown in figure 1)

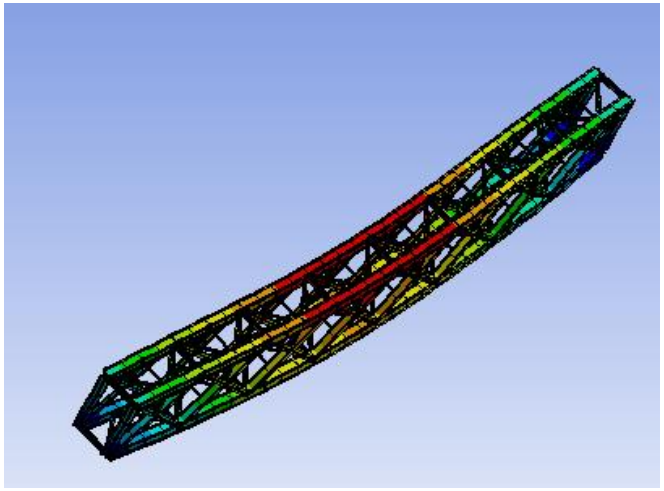

Figure 3– First lateral mode shape at 3.4 Hz (Cos Cob Bridge, Ct, Span 3)

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:

- Procedure established - Bridge vibration velocities due to moving trains measured from the field tests at various points using Laser Doppler Vibrometer can be converted to displacement and analyzed for stresses. Similarly, the measured bridge oscillation velocities can be processed to get acceleration from which dynamic parameters such as damping ratio and natural frequencies can be extracted and analyzed.

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:

- N/A

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:

- The increase the body of knowledge and technologies by comparing different type of inspection equipment.

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 & Title	Dates involved	Email Address	Department	Role in Research
Dr. Ramesh B. Malla (Principal Investigator), Professor	Jan.-Mar. 2022	Ramesh.Malla@UCONN.EDU	Department of Civil & Environmental Engineering, University of Connecticut, Storrs	Principal Investigator (PI)/ TIDC Institutional Lead, UConn

*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.)*

Table 7: Student Participants during the reporting period								
Student Name	**Start Date**	**End Date**	**Advisor**	**Email Address**	**Level**	**Major**	**Funding Source**	**Role in research**
				Email is not included in the external report and is only used for internal purposes.	*(i.e. UG, MS, PhD)*		*(i.e. TIDC, Other university funds, , unpaid intern, etc.*	*What work are they conducting? Please be descriptive. Student research assistant is not enough info.*
Celso de Oliveira	Jan. 01, 2022	Mar. 31, 2022	Dr. Ramesh Malla		Ph.D.	Civil Eng.	TIDC/UConn	Field Test and FEM
Santosh Dhakal	Jan. 01, 2022	Mar. 31, 2022	Dr. Ramesh Malla		M.S.	Civil Eng.	TIDC/UConn	Material Test
Suvash Dhakal	Jan. 01, 2022	Mar. 31, 2022	Dr. Ramesh Malla		Ph.D.	Civil Eng.	N/A	Supporting role as needed

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 or if they are continuing their studies through an advanced degree).

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?**
			Please list the organization or degree
N/A	N/A	N/A	N/A.

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?**
			Please list the organization or degree
N/A	N/A	N/A	N/A

*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**
		List the amount	List the amount	Mark with an "x" where appropriate		
Conn DOT Contact persons: (1) Haresh Dholakia, Transportation Engineering Supervisor, Rail Design *(Technical Champion)* (2) Mr. Manesh Dodia, Supervising Rail Officer, Rail Construction *(Technical Champion)*	Newington, CT		X	X	X	
Maine DOT Contact Persons: (1) Dale Peabody- TIDC Advisory Board, Director Transportation Research (2) Brian Reeves- Director of Rail Transportation	Augusta, ME		X	X	X	
Metro-North Railroad Co. Contact persons:	Bridgeport, CT		X	X	X	

(1) Warren Best-Assistant Deputy Director- Structures *(Technical Champion)* (2) Ms. Hong McConnell, Senior Structural Engineer						
Polytec, Inc., Hudson, MA Contact Person: Mr. Mario Pineda, Territory Manager	Hudson, MA		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.*

Table 11: Other Collaborators

Collaborator Name and Title	Contact Information	Organization and Department	Date(s) Involved	Contribution to Research
	For internal use only			*(i.e. technical champion, technical advisory board, test samples, on-site equipment, data, etc.)*
Haresh Dholakia, Transportation Engineering Supervisor, Rail Design		Connecticut Department of Transportation (Conn DOT), Newington, CT	Jan.-Mar. 2022	Technical Champion
Manesh Dodia, Supervising Rail Officer, Rail Construction		Connecticut Department of Transportation (Conn DOT), Newington, CT	Jan.-Mar. 2022	Technical Champion
Warren Best, Assistant Deputy Director-Structures		Metro-North Railroad Company, Bridgeport, CT	Jan.-Mar. 2022	Technical Champion
Hong McConnell, Senior Structural Engineer		Metro-North Railroad Company, Bridgeport, CT	Jan.-Mar. 2022	Coordinator for logistics for field test on bridges
Mario Pineda, Territory Manager		Polytec Inc., Hudson, MA	Jan.-Mar. 2022	Providing part of the field test Equipment (Laser Vibrometer) and advice conducting field tests.

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**
i.e. CE 123		Grad or undergrad?	Where was the course taught?	Who taught the course?	Enter Spring, Fall, Summer, Winter and the year	How many students were enrolled in the class?
CE 5122-001	Advance Mechanics of Material	Grad	Storrs, CT	Prof. R. Malla	Spring 2022	9
CE 3630-001	Design of Steel Structures	Undergrad / lab	Storrs, CT	Celso de Oliveira (Teaching Assistant)	Spring 2022	30
CE 4510-001	Foundation Design	Undergrad	Storrs, CT	Santosh Dhakal (Teaching Assistant)	Spring 2022	60

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.

- Work on logistic and collect equipment's for the summer field test.
- Complete bridge material stress-stain tests.
- Perform simulation to study the interaction between the bridge and the vehicle.
- Continue working on to investigate the optimal number and location of sensor for bridge health monitoring.

- Maintain communication with CT and other New England DOTs, Metro-North Railroad company, and Polytec, Inc., so that the research will be relevant and of value to the DOTs and industry.
- Prepare and submit the project final report.