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: October 01, 2021, to December 31, 2021
Submission Date: December 31, 2021

****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.

Overview:

*Provide **BRIEF** highlights of activities performed during the reporting period. This summary should be written in lay terms for a general audience to understand. This should not be an extensive write up of findings (those are to be included in the final report), but a high-level overview of the activities conducted during the last three months **no more than 3 bullet points at no more than 1 sentence each** ….*

- The original material specimens from the Devon bridge (CT), Cos Cob bridge (CT), Atlantic Street bridge (CT), and the Sheridan/Aroostook River bridge (ME) members replaced in the past maintenance, have been tested under tension following ASTM E8-16 standard.
- The velocity time domain response obtained from the field test of Devon Bridge (span 7), Figure 1, under service, using a Single-Point Laser Doppler Vibrometer was processed and analyzed to extract the dynamic parameters such as vertical displacement and damping ratio).
- Devon bridge Finite Element Model has shown good agreement in first 3 natural frequencies, and in vertical displacement in comparison with the field test using a Single-Point Laser Doppler Vibrometer (Figure 2).

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.

- The material characterization tests from different old bridges will allow the research team to understand and evaluate the durability and actual condition of the old steel, in this case the ASTM-A7.
- The velocity time-domain response obtained from the Single-Point Laser Doppler Vibrometer can be converted to displacement or acceleration and converted in frequency-domain using Fast Fourier Transform. Velocity time-domain can be easily integrated or derived from the Laser Doppler Vibrometer output.
  The updated model will be used to simulate different type of trains running at specified maximum allowable speed at the bridge. The maximum displacement will be compared and correlate with the Copper load from AREMA.

Accomplishments:

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

- Tensile stress-strain curves have been obtained for the material specimen from Devon bridge (CT), Cos Cob bridge (CT), Atlantic Street bridge (CT), and the Sheridan/Aroostook River bridge (ME)
- The velocity time-domain response obtained from the field tests of Devon bridge using the Single-Point Laser Doppler Vibrometer have been successfully processed to obtain displacements with time at key locations in the bridge.
- Devon bridge Finite Element Model has shown good agreement in comparison with the field test using a Single-Point Laser Doppler Vibrometer in frequency-domain, and in time-domain.

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: Literature search and review; communication with New England state DOTs for railroad bridge material collection and information/data	October 1, 2018	December 31, 2020	95%
Task 2: Existing railroad bridge material testing	January 1, 2019	August 31, 2021	80%
Task 3: Finite Element (FE) modeling of railroad bridge	June 1, 2019	December 31, 2021	90%
Task 4: Determine optimal number and locations of sensor for effective bridge condition monitoring	December 1, 2019	January 31, 2022	30%
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	30%
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	60%
Final Report preparation and submission	January 1, 2022	June 30, 2022	0%
Overall Project:	October 01, 2018	June 30, 2022	85%

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 (Federal + Cost Share)*	*Enter Phase 1 % Spent*
To be provided separately	To be provided separately	To be provided separately

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 with December 21, 2021 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..

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. 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)
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?*		
Conference Presentation	"Railroad Bridge Field Test Investigation of Live Load Impact as a Function of Train Speed"	Jacobs, D.W. and Malla, R. B., "Railroad Bridge Field Test Investigation of Live Load Impact as a Function of Train Speed," 34th Rhode Island Transportation Forum, Kingston, RI; October 29, 2021	34th Rhode Island Transportation Forum Audience: Transportation industry, town/state/federal agencies, and academicians	Kingston, RI	October 29, 2021
Workshop/Symposium/Webinar	Symposium on New England Railroad Infrastructure – Challenges, Solutions and Opportunities	Malla, R.B. (Co-lead organizer with M. Shin, D. Peabody, J. Bryce, and A. Collamore) "Symposium on New England Railroad Infrastructure – Challenges, Solutions and Opportunities," *Virtual webinars*, U.S. DOT Region 1 UTC- TIDC; Nov. 10, 2021	2021 TIDC Symposium on New England Railroad Infrastructure – Challenges, Solutions and Opportunities Audience: Transportation industry, town/state/federal agencies, and academicians (faculty and students)	Virtual	November 10, 2021

Workshop/Symposium/webinar	Session title: Session 3: Solutions & Opportunities: at the "Symposium on New England Railroad Infrastructure – Challenges, Solutions and Opportunities,	Malla, R.B. (Session Co-Chair with J. Gordon, FRA), Session Title: Session 3: Solutions & Opportunities: at the "Symposium on New England Railroad Infrastructure – Challenges, Solutions and Opportunities," *Virtual webinars*, U.S. DOT Region 1 UTC- TIDC; Nov. 10, 2021	2021 TIDC Symposium on New England Railroad Infrastructure – Challenges, Solutions and Opportunities Audience: Transportation industry, town/state/federal agencies, and academicians (faculty and students)	Virtual	November 10, 2021
Graduate Seminar	"Railroad Bridge: Basics, Eyebars, and Impacts" and/or "Why we won't see high speed rail in the United States"	Jacobs, David ,"Railroad Bridge: Basics, Eyebars, and Impacts" and/or "Why we won't see high speed rail in the United States," CVE601 Graduate Seminar, University of Rhode Island, Kingston, RI; Nov. 12, 2021	CVE601 Graduate Seminar, University of Rhode Island; Audience: Graduate students	Kingston, RI	November 12, 2021

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)*
Conference Abstract	Monitoring of Old Truss Railroad Bridge under Free and Service Vibration using Laser Doppler Vibrometers	de Oliveira, C., Dhakal, S., and Malla, R. B. , "Monitoring of Old Truss Railroad Bridge under Free and Service Vibration using Laser Doppler	October 18, 2021 (Date submitted)	Under review

		Vibrometers," 2022 International Bridge Conference, Pittsburgh, PA, July 17-20, 2022		
Journal	Frequencies, Mode Shapes and Finite Element Model Verification of a Long Span Open Deck Through Truss Railroad Bridge from Field Tests	By Dhakal, S., Baniya, S., Jacobs, D., and Malla, R.B., "Frequencies, Mode Shapes and Finite Element Model Verification of a Long Span Open Deck Through Truss Railroad Bridge from Field Tests," ASCE J. of Bridge Engineering	October 2021	Under review
Ph.D. Dissertation	Dynamic Impact Factors Produced by Trains on Long Span Open Deck Steel Truss Railroad Bridges	Jacobs, David, "Dynamic Impact Factors Produced by Trains on Long Span Open Deck Steel Truss Railroad Bridges," Ph.D. Dissertation (Advisor: R.B. Malla), University of Connecticut, Storrs, CT: Dec. 2021	Dec. 2021	Accepted/Approved

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.

Insert figures here

Figure 1 – Devon Bridge (CT), Span 7, P1 location

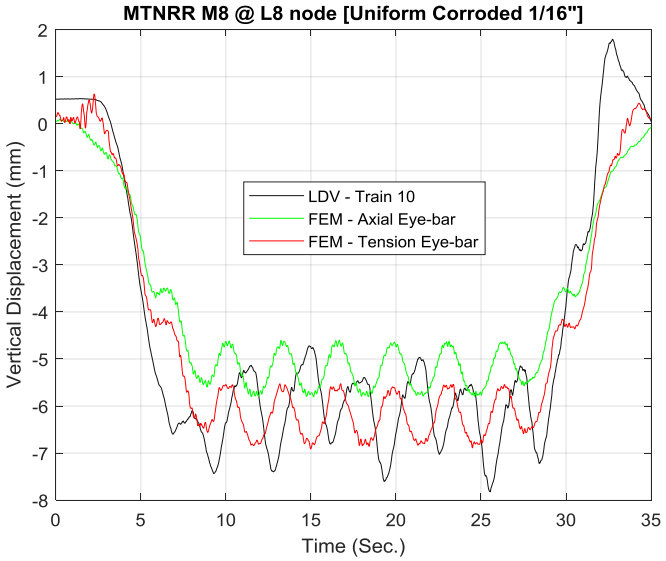

Figure 2 – Vertical Displacement with time from Field test vs Finite Element Model (FEM) – Metro-North Train M8 at P1 location

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	Oct-Dec. 2021	Ramesh.Malla@UCONN.EDU	Department of Civil & Environmental Engineering, University of Connecticut, Storrs	Principal Investigator (PI)/ TIDC Institutional Lead, UConn
Dr. Lesley D. Frame, Assistant Professor	Oct-Dec. 2021	Lesley.Frame@UCONN.EDU	Department of Materials Science & Engineering, University of Connecticut, Storrs	Support and advice: Material characterization of the test specimens
Dr. Nicholas Eddy Assistant Professor	Oct-Dec. 2021	Nicholas.Eddy@UCONN.EDU	Institute of Material Science, University of Connecticut, Storrs	Support and advice: Mechanical Testing Lab

*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**
				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	Oct. 01, 2021	Dec. 31, 2021	Dr. Ramesh Malla		Ph.D.	Civil Eng.	TIDC/UConn	Field Test and FEM
Santosh Dhakal	Oct. 01, 2021	Dec. 31, 2021	Dr. Ramesh Malla		M.S.	Civil Eng.	TIDC/UConn	Material Test
David Jacobs	Oct. 01, 2021	Dec. 31, 2021	Dr. Ramesh Malla		Ph.D.	Civil Eng.	N/A	Supporting role as needed
Suvash Dhakal	Oct. 01, 2021	Dec. 31, 2021	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 (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?**
			Please list the organization or degree

David Jacobs	Ph.D.	December 2021	Yes, Teaching at the University of Hartford.

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: (1) Warren Best-Assistant Deputy Director- Structures *(Technical Champion)* (2) Ms. Hong McConnell, Senior Structural Engineer	Bridgeport, CT		X	X	X	
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. (**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
	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	HareshKumar.Dholakia@CT.GOV	Connecticut Department of Transportation (Conn DOT), Newington, CT	Oct-Dec. 2021	Technical Champion
Manesh Dodia, Supervising Rail Officer, Rail Construction	Manesh.Dodia@CT.GOV	Connecticut Department of Transportation (Conn DOT), Newington, CT	Oct-Dec. 2021	Technical Champion
Warren Best, Assistant Deputy Director-Structures	Best@MNR.ORG	Metro-North Railroad Company, Bridgeport, CT	Oct-Dec. 2021	Technical Champion
Hong McConnell, Senior Structural Engineer	McConnell@MNR.ORG	Metro-North Railroad Company, Bridgeport, CT	Oct-Dec. 2021	Coordinator for logistics for field test on bridges

Mario Pineda, Territory Manager	M.Pineda@POLYTEC.COM	Polytec Inc., Hudson, MA	Oct-Dec. 2021	Providing part of the field test Equipment (Laser Vibrometer) and advice conducting field test

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 211-020	Applied Mechanics I	Undergrad	Storrs, CT	Prof. R. Malla	Fall 2021	120
CE 5542/CE 4542	Earthquake Engineering	Grad & Undergrad	Storrs, CT	Prof. R. Malla	Fall 2021	9
CE 3640	Design of Reinforced Concrete Structures	Undergrad / lab	Storrs, CT	Celso de Oliveira (Teaching Assistant)	Fall 2021	33
CE 2110-020D & 022D	Applied Mechanics I	Undergrad / Discussion	Storrs, CT	Santosh Dhakal (Teaching Assistant)	Fall 2021	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.

In following months, the research team will continue:

- Performing in-depth processing of the data collected from both the Cos Cob and the Devon bridges field tests performed on last summer.
- To working on material characterization.
- To calibrating the FE model of the Cos Cob bridge.
  Maintaining 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.