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Recipient Organization (name and address): The University of Maine, Transportation Infrastructure Durability Center, 35 Flagstaff Road, Orono, Maine 04469

Recipient Identifying number or account number, if any: N/A

Project/grant period: 6/5/2018 – 9/30/2023

Reporting Period end date: 3/31/2021

Report term or frequency: Semi-Annual

Signature of submitting official:

I. ACCOMPLISHMENTS

a. What are the major goals and objectives of the program?

Research

The over-arching research objective of the TIDC is to improve the durability and extend the life of transportation infrastructure, including roads, bridges, and rail facilities. This objective will be achieved through (1) fundamental and applied research that will broaden our overall knowledge base while providing practical solutions to the state and federal agencies responsible for constructing and maintaining the nation's transportation facilities; (2) educational offerings in various fields of transportation that include comprehensive course work and student participation in research; (3) workforce development activities and programs to expand the workforce of transportation professionals; and (4) a perpetual program of technology transfer to ensure TIDC research results are disseminated and applied as widely as feasible.

Specific research projects are selected through a combination of peer-review and state DOT/industry input, and are expected to fall within TIDC's four research thrust areas identified in the table below.

Table 1: TIDC Research Thrusts Areas

Thrust Area Title	Description
Thrust Area 1: Transportation Infrastructure Monitoring and Assessment for Life	Managing aging civil infrastructure is a major challenge facing every country in the world. Research conducted under this theme tackles this issue through the development and implementation of novel strategies for the assessment and health monitoring of highway bridges, rail structures, pavements, slopes, embankments, and foundations. The ability to monitor the performance and health of these vital elements will provide the information required to prioritize the repair and replacement of our transportation infrastructure, while advanced assessment will justify extending the service life of these assets.
Thrust Area 2: New Materials for Longevity and Constructability	This thrust investigates new materials and technologies to improve durability and extend the life of transportation infrastructure. The materials and technologies investigated can apply to a range of transportation modes (vehicular, rail, etc.).
Thrust Area 3: New Systems for Longevity and Constructability	This research thrust focuses on evaluation, development, performance, reliability, and application of engineering systems to improve the durability and longevity of new and existing transportation infrastructure. New England's transit networks face challenges related to cold weather, changing climate, age-related deterioration, evolving load demands, construction efficiencies, and congestion, among others. In these times of economic austerity, innovative engineering systems are needed to alleviate existing and future financial strain on the region.
Thrust Area 4: Connectivity for Enhanced Asset and Performance Management	The system operational efficiency of transportation infrastructure can be improved by smart technologies that connect the infrastructure to information/management systems, vehicles, and roadway users. These emerging, connected technologies – coupled with appropriate and evolving management systems – can improve the durability of existing and new infrastructure. This is essential in the coming age of highly automated, connected vehicles and given the need to improve the performance of the existing infrastructure through more cost-effective and targeted assessments of asset vulnerabilities due to extreme weather events. This research theme applies to all forms of infrastructure including highway, railroad, marine ports, and airports.

TIDC will provide base funding to each member university contingent upon performance. Additional funding of $250,000 will be made available through an annual competitive RFP process.

Base and competitive funding are contingent upon performance, and all funded activities must meet metrics defined in technology transfer, education and workforce development, and collaboration. Each member university will provide performance metrics information to UMaine through quarterly progress reports for each research project to ensure performance is adequately tracked.

Education & Workforce Development

TIDC seeks to attract a more diverse pool of talented students into careers in science and engineering and ensure that these students receive the best education possible. Beyond providing students with a detailed knowledge of existing public transportation infrastructure and system challenges in the realm of durability and life extension, TIDC activities will (1) enhance student communication skills to ensure they can reach a variety of audiences including researchers, the public, and decision-makers; (2) create an inclusive multi-cultural and multi-disciplinary student body by recruiting women and underrepresented racial and ethnic groups into our program; and (3) foster the development of leadership skills through vertically integrated research teams (faculty, post-docs when applicable, graduate students, and undergraduate students) and peer mentoring. Undergraduate and graduate students will be directly supported by TIDC research projects and make meaningful contributions under the mentoring and guidance of faculty that is essential to student success.

TIDC will strengthen diversity and STEM education by sharing research with future members of the workforce at middle and high schools. This will include both exposing young people to opportunities that exist within the field of transportation infrastructure and engaging them in transportation-related educational activities.

Formal metrics to measure program effectiveness include numbers of undergraduate and graduate students participating in intra-consortium exchange initiatives or industrial internships; seminars, workshops, and conferences hosted; number of K-12 students who participate in transportation-focused tours or activities at member institutions; total number of classrooms reached by TIDC activities, including specifics on classrooms populated by under-represented groups of students.

Technology Transfer

The technology transfer objective of TIDC support the TIDC mission through their emphasis on research impact and dissemination. The projects funded by TIDC will meet the following objectives: (1) Ensure research developments and findings are accessible, disseminated, and transferred to a variety of users; and (2) Ensure research developments have long-term value and significant impact to the transportation industry through collaboration with government, industry partners, and non-profit organizations. The TIDC goals and performance metrics reflect the full spectrum of research activities through technology concept inception and assessment to technology adoption. The projects funded by TIDC will support the following technology transfer activities: (1) development of new technologies, techniques, or methodologies; (2) publishing journal, conference and policy papers that become references for practitioners for the modification of codes and standards for technology adoption; (3) deployment of new technologies, techniques, or practices; (4) improvements in the processes, technologies, and techniques in addressing transportation issues; (5) workforce development; (6) adoption of technologies, techniques, or practices; and, (7) development or modification of codes and standards to facilitate wider technology adoption.

As identified in the TIDC Technology Transfer Plan, the Center's mission is to develop innovative, sustainable, next-generation solutions to improve the durability and extend the lifespan of existing and new transportation assets in New England and beyond. TIDC is committed to making dramatic impacts in the cost-effectiveness of transportation infrastructure through transformative research, education, outreach, workforce development, and technology transfer through four research thrust areas; 1) monitoring and assessment, 2) new materials for longevity and constructability, 3) new systems for longevity and constructability, and 4) connectivity for enhance asset and performance management.

TIDC's technology transfer objectives are:

- Ensure research developments and findings are accessible, disseminated, and transferred to a variety of users.
- Ensure research developments have long-term value and significant impact to the transportation industry through collaboration with government and non-profit organizations.

Formal metrics to measure technology transfer goals include successfully demonstrated proof-of-concept; number of technical reports published; number of relevant papers published through peer-reviewed journals; number of relevant papers published in conferences, symposia, workshops, and meetings; number of technologies deployed in transportation applications through pilot or demonstration studies; number of research deliverables disseminated; number of webinars given; number of instances of technology adoption by Industry or transportation agencies and of commercialization; and, number of instances of research changing Industry or transportation agency practices, decision making, or policies.

As part of TIDC's Technology Transfer Plan (dated March 31, 2021) the following technology transfer goals and performance measures were established:

Table 2: Technology Transfer Goals & Performance Measures

Goal	Performance Metrics	Target
Output: Develop new technologies, techniques, or methodologies	Number of successfully demonstrate proof-of-concept activities for newly developed technologies, techniques, or methodologies	2
Output: Publish journal, conference, and/or policy papers that become references for practitioners for the modification of codes and standards for technology adoption	Number of technical reports, theses, dissertations, DOT reports, and other report types submitted and/or published	5
	Number of papers published in peer-reviewed journals	4
	Number of papers, abstracts, or posters published and/or presented in conferences, symposia, workshops, and/or meetings	12
Outcome: Deploy new technologies, techniques, or practices	Number of technologies deployed in transportation applications through pilot or demonstration studies	2
Outcome: Improve the processes, technologies, and techniques in addressing transportation issues	Number of licenses granted to industry or patent applications submitted	1
Impact: Workforce development	Number of webinars given to disseminate findings to industry professionals	6

	Number of seminar, workshop, and/or conference sessions led by researchers to present findings of research activities to industry professionals	45
Impact: Adoption of technologies, techniques, or practices	Number of instances of technology adoption by industry or transportation agencies and of commercialization	1
	Number of instances that TIDC supported findings were referenced, cited, or mentioned in journal articles, presentations given by others not active in the research project, newspaper or magazine articles, etc.	5
Impact: Development or modification of codes and standards to facilitate wider technology adoption	Number of instances of research changing industry or transportation agency practices, decision making, or policies	1

Collaboration

Institutional leads will serve on the TIDC Management Team which will help to ensure each institution has ownership and is committed to the success of the program. Additionally, in an effort to ensure all TIDC research projects are relevant to Department of Transportation and/or Industry needs, each TIDC research project has a Technical Champion. The Technical Champion has subject matter expertise and serves as a resource for the principal investigators. The Technical Champion will help integrate the research results into DOT or Industry practice and will help with the implementation or project results during and after the research. Technical Champions on each project are providing in-kind support and are not monetarily compensated for the time they spend working with the principal investigators. As more projects are added and advanced, the number of Technical Champions and their contributions will change. See table 5 on page 10 for a complete list of Technical Champions.

To ensure the successful selection and implementation of relevant research projects, TIDC has assembled an Advisory Board. The role of the Advisory Board is to ensure TIDC continues to meet the needs and challenges of Region 1 within its designated Fast Act topic. The Advisory Board evaluates and recommends the disbursement of competitive funding through an open RFP process to support additional activities at member universities. The Advisory Board also reviews TIDC's annual performance metrics from each member university to determine the status of performance based base funded projects. The Advisory Board is currently comprised of members from state DOTs in Region 1.

Formal metrics to measure collaboration goals include presentations given at non-member universities, documented conversations regarding collaboration between TIDC and other UTCs, the number of industrial partners and state DOTs participating in TIDC research, dollar amount of state DOT and industry invested into TIDC research projects, number of technical champions actively involved in TIDC research projects, and number of outside attendees to the TIDC Annual Conference.

b. What was accomplished under these goals?

Research

In order to ensure TIDC is conducting relevant and transferable research projects, individual projects are required to submit periodic reports to ensure the approved goals and objectives of each research project are being met and are working toward TIDC's mission and research goals. During this reporting period, TIDC has 40 projects that were active during the reporting period. See Table 3 for a list of all TIDC funded research projects that were active and selected during the reporting period.

Table 3: TIDC Projects Active During the Reporting Period

Project Number & Title Institution	Institution(s)	Start Date
Thrust Area 1: Transportation Infrastructure Monitoring and Assessment of Enhanced Life		
1.2 – Condition/Health Monitoring of Railroad Bridges for Structural Safety, Integrity, and Durability	University of Connecticut	10/1/2018
1.4 – Electromagnetic Detection and Identification of Concrete Cracking in Highway Bridges	University of Massachusetts Lowell	1/1/2019
1.5 – Distributed Fiber Optic Sensing System for Bridge Monitoring	University of Massachusetts Lowell	1/1/2019
1.6 – Progressive Fault Identification and Prognosis of Railway Tracks Based on Intelligent Inference	University of Connecticut	10/1/2018
1.8 – Enhancing Intelligent Compaction with Passive Wireless Sensors	University of Vermont	7/1/2018
1.12 – Improved UAV-Based Structural Inspection Techniques & Technologies for Northeast Bridges	University of Maine	10/1/2020
C3.2018 – Condition Assessment of Corroded Prestressed Concrete Bridge Girders	University of Massachusetts Lowell & Western New England University	1/1/2019
C5.2018 – Leveraging High-Resolution LiDAR and Stream Geomorphic Assessment Datasets to Expand Regional Hydraulic Geometry Curves for Vermont: A Blue Print for New England States	University of Vermont	6/1/2019
C11.2019 – Development of System-Level Distributed Sensing Technique for Long-Term Monitoring of Concrete and Composite Bridges	University of Massachusetts Lowell, University of Vermont, University of Maine	10/1/2020
C19.2020 – Damage Modeling, Monitoring, and Assessment of Bridge Scour and Water Borne Debris Effect for Enhanced Structural Life	University of Connecticut	10/1/2020
C20.2020 – Advanced Sensing Technologies for Practical UAV-Based Condition Assessment	University of Maine	10/1/2020
Thrust Area 2: New Materials for Longevity and Constructability		
2.2 – Concrete Systems for a 100-Year Design Life	University of Maine	3/1/2020
2.3 – Avalanche study of the fiber-reinforced cementitious composites	University of Vermont	7/1/2020
2.4 – Thermoplastic Composites by 3D Printing and Automated Manufacturing	University of Maine	1/1/2019

2.5 – Development and testing of High/Ultra-High Early Strength Concrete for Durable Bridge Components and Connections	University of Connecticut	10/1/2018
2.7 – High Performance Concrete with Post-Tensioning Shrinking Fibers	University of Vermont	1/1/2019
2.9 – Carbonating Subgrade Materials for In Situ Soil Stabilization	University of Maine	9/1/2018
2.10 – Durability Evaluation of Carbon Fiber Composite Strands in Highway Bridges	University of Maine	6/1/2019
2.11 – Culvert Rehabilitation Using 3D Printed Diffusers	University of Maine	7/1/2020
2.12 – Evaluation of Processed Glass Aggregate for Utilization in Transportation Projects as a Sand Borrow	University of Vermont	10/1/2020
2.13 – Performance Structural Concrete Optimized for Cost, Durability, and Manufacturability	University of Vermont	10/1/2020
C7.2018 – Alternative Cementitious Materials (ACMs) For Durable and Sustainable Transportation Infrastructures	University of Maine	6/1/2019
Thrust Area 3: New Systems for Longevity and Constructability		
3.4 – Testing, Monitoring, and Analysis of FRP Girder Bridge with Concrete Deck	University of Maine	3/1/2019
3.5 – Prevention of Stressed-Induced Failures of Prestressed Concrete Crossties of the Railroad Track Structure	Western New England University	9/1/2018
3.7 – Development of General Guidelines on the Effects of Bridge Span Range and Skew Angle Range on Integral Abutment Bridges (IAB's)	University of Massachusetts Lowell	7/1/2018
3.8 – Bridge Modal Identification via Video Processing and Quantification of Uncertainties	University of Massachusetts Lowell	11/1/2018
3.10 – Assessment and Optimization of Double CT Bridge Girder Sections with Longitudinal Precast Decks	University of Maine	7/1/2020
3.11 – Assessment of Micropile-Supported Integral Abutment Bridges	University of Maine	9/1/2019
3.12 – Lateral Loading of Unreinforced Rigid Elements and Basal Stability of Column-Supported Systems	University of Maine	6/1/2019
3.13 – Investigating the Effectiveness of Enzymatic Stabilizers for Reclaimed Stabilized Base Products	University of Vermont	10/1/2020
3.14 – FRP-Concrete Hybrid Composite Girder Systems: Web Shear Strength and Design Guide Development	University of Maine	10/1/2020
C9.2019 – A New Method for Determining Payment for In-Pace Concrete with Double-Bounded Compressive Strength Pay Factors	University of Vermont	10/1/2020
C17.2020 – Durability of Modified Helical Piles under Lateral and Torsional Loads: Embracing Efficient Foundation Alternative to Support Lightweight Transportation Structures	University of Maine & University of Rhode Island	10/1/2020
Thrust Area 4: Connectivity for Enhanced Asset and Performance Management		
4.1 – Highly Automated Vehicles and Bridge Infrastructure	University of Maine	9/1/2018

4.2 – Future-Proof Transportation Infrastructure through Proactive, Intelligent, and Public-involved Planning and Management	University of Connecticut	10/1/2018
4.3 – Towards Quantitative Cybersecurity Risk Assessment in Transportation Infrastructure	University of Connecticut	10/1/2018
4.4 – Bridge-stream Network Assessments to Identify Sensitive Structural, Hydraulic, and Landscape Parameters for Planning Flood Mitigation	University of Vermont	7/1/2018
4.9 – Analysis of Covid-19 and Travel In Maine (ACTIME) – Validation Study	University of Maine	8/1/2020
4.10 – Road Salt Impact Assessment	University of Maine	8/15/2020
4.11 – Safety Assessment of New England Roadways during the COVID-19 Pandemic	University of Maine	9/15/2020

Due to the continued impact of COVID-19 on the member universities, some researchers were still unable to obtain full access to their labs during the reporting period. As certain restrictions were lifted throughout the region, projects were able to achieve/meet the goals of the research projects. The following are a few examples of accomplishments achieved under individual research projects. More TIDC research accomplishments can be found in sections III and IV of this report and on the TIDC website on each research project's individual page.

After an internal review of all of the active TIDC research projects, four research projects were terminated due to the quality of the research not meeting the mission, goals, and objectives of TIDC and due to the lack of outputs and high-quality internal reporting. The projects terminated during this reporting period are as follows: (1) Project 1.11 – Energy Harvesting and Advanced Technologies for Enhanced Life; (2) Project 2.1 – Asphalt Mixtures with Crumb Rubber Modifier for longevity and Environment; (3) Project 3.6 – Recycling Infrastructure Assets and Reduction of Transportation System Greenhouse Gas Emissions; and (4) Project 4.7 – Integrated Green Infrastructure and Sustainable Transportation Planning.

Education & Workforce Development

The TIDC Program Coordinator completed the creation of the curriculum to be turned into an approved 4-H STEM toolkit at the beginning of 2020. While existing 4-H STEM Toolkits provide an experiential science learning opportunity for youth by providing materials needed to successfully complete science-based activities, TIDC's transportation related toolkit will be used to encourage youth to learn more about the transportation industry. The curriculum was scheduled to be piloted beginning in February and March of 2020 in four classrooms at an elementary school in Orono, ME. After the completion of the pilot, TIDC Administration at UMaine was to meet with the elementary school teachers to receive feedback and make recommended adjustments to the curriculum before releasing the curriculum to the rest of the school and additional elementary schools in the State of Maine. Unfortunately, due to the continued COVID-19 restrictions in place in the K-12 school systems, the curriculum implementation was unable to begin in the spring of 2021 as planned at the writing of the previous report. TIDC has tentatively rescheduled the implementation of the created curriculum for the 2021-2022 school year. It is TIDC's revised goal to receive final approval in the fall of 2022 for an official 4-H toolkit that can be distributed to schools in the state of Maine and other 4-H participating states in Region 1.

Additionally, in an effort to encourage more individuals to enter the transportation field, TIDC collaborated with the Maine Engineering Promotional Council (MEPC) during the planning process, with the TIDC

Program Coordinator acting as a member of the Board, and at the virtual event on February 27, 2021. The MEPC works to increase the visibility of engineering in Maine through two Engineering Events, an Engineering Banquet and the Engineering Expo. THE MEPC Board is comprised of academic and industry members who are all committed to raising awareness of engineering through the Banquet and Expo events.

In an effort to provide more workforce development opportunities, the TIDC Program Coordinator met with workforce development personnel at the Roux Institute and the Maine Community College System. The goal is to create partnerships to provide credentialing opportunities to professionals in the transportation field. The program would be piloted in Maine and, upon its success, will be extended to the other states in the region.

Student researchers at member universities have been disseminating research findings through poster presentations, seminars, and conferences. Students have also participated in webinars and professional development opportunities. TIDC faculty taught 16 undergraduate courses and 17 graduate courses during the reporting period.

Technology Transfer

TIDC research results have been disseminated through a variety of ways including the TIDC website and social media platforms.

TIDC researchers have participated in 9 conferences, workshops, and/or seminars during the reporting period. The following table indicates the conferences and workshops attended by TIDC researchers and the activity they conducted to disseminate information during this reporting period.

Table 4: Conferences, Workshops, and Seminars

Name of Conference/Workshop	Activity	Location	Dates
45th Annual Conference on Deep Foundations	Conference	Virtual	10.29.2020
ITHEC 2020 - 5th International Conference & Exhibition on Thermoplastic Composites	Conference	Virtual	10.13.2020-10.15.2020
TIDC Annual Student Poster Contest	Poster Presentations	Virtual	10.21.2020
33rd Rhode Island Transportation Forum	Symposium	Virtual	10.30.2020
2021 Transportation Research Board Annual Meeting	Conference	Virtual	1.25.2021-1.29.2021
Illinois DOT Presentation	Presentation	Virtual	2.8.2021
ANTEC 2021 Society of Plastic Engineers	Conference	Virtual	3.22.2021-3.23.2021
2021 SPIE SS/NDE Conference Nondestructive Characterization and Monitoring of Advanced Materials, Aerospace, Civil Infrastructure, and Transportation XV	Conference	Virtual	3.22.2021
SPIE Smart Structure & Nondestructive Evaluation Conference	Conference	Virtual	3.22.2021-3.26.2021

Additionally, TIDC has published or submitted 2 journal papers/articles, 6 conference papers, 1 conference abstract, and 5 other publications and presentations during the reporting period. For a complete list of the submitted papers, please see Section III, Outputs.

Collaboration

Critical to TIDC's success is the development of partnerships and collaborations with state DOT's, the transportation industry, transportation professionals, and various stakeholders that assist in addressing the center goals.

During this reporting period, the TIDC Management Team met each month, with the exception of December, for a total of five meetings. All five meetings were held via Zoom. The Semi-Annual in person meeting was unable to happen in November due to COVID travel restrictions.

Equally as important to the collaboration with the TIDC Advisory Board and the inter-institutional collaboration is the collaboration that happens with the Technical Champions (TC), industry partners, and State DOT (including maintenance and operations) collaborators. All TIDC funded projects have met the goal of having a Technical Champion (as described in Section I a, Collaboration) assigned to each. Some research projects have additional Technical Champions and Advisors involved in their projects. Each PI is responsible for submitting their quarterly reports to their TC and working with them to ensure their research with have the greatest impact on the transportation industry. In addition to sending their reports to the TC, PIs from multiple projects are meeting with their TC to discuss and adapt their research.
Additionally, TIDC is actively working with industry partners during their research efforts. For example, the research team for Project 3.4 (UMaine) met with AIT Bridges, MaineDOT, and T Buck Construction to provide feedback on the installation of the composite tub girders, now called GBeams, in the Grist Mill Bridge in Hampden, ME. These meetings and collaborative efforts help ensure the commercialized and future accepted use of new technologies being developed by the Center. More collaborations and stakeholders are identified in table 5 below.

The following table identifies the 49 active Technical Champions and Advisors involved in TIDC research projects during this reporting period. (* Indicates newly added Technical Champions and Advisors during this reporting period.)

Table 6: Active Technical Champions & Advisors

Name and Title of Technical Champion or Advisor	Organization
August Arles, Geotechnical Engineer*	Vermont Agency of Transportation
Andrew Bardow, Director, Bridges and Structures	Massachusetts Department of Transportation
Mary Baker, Transportation Principal Engineer	Connecticut Department of Transportation
Raymond Basar,	Connecticut Department of Transportation
Warren Best, Assistant Deputy Director, Structures	Metro-North Railroad Company
Tanner Blackburn, Chief Geotechnical Engineer	Hayward Baker
Robert Blunt, Project Manager*	VHB
Peter J. Calcaterra, Transportation Planner	Connecticut Department of Transportation
Henry Chango, Contract Administrator	D'Ambra Construction Company, Inc.
David Cist, Chief Technology Officer*	Geophysical Survey Systems, Inc. (GSSI)
Bao Chuong,	Connecticut Department of Transportation
Brian Clang, Bridge Inspection Engineer	Massachusetts Department of Transportation
Cassidy Cote, Hydraulics and Structures Engineer	Vermont Agency of Transportation
Joseph Cristalli, Transportation Principal Safety Program Coordinator*	Connecticut Department of Transportation
Jeff DeGraff, P.E., Hydraulics Project Engineer*	Vermont Agency of Transportation

Haresh Dholakia, Transportation Engineering Supervisor	Connecticut Department of Transportation
Manesh Dodia, Transportation Engineer	Connecticut Department of Transportation
Shawn Downey, Senior Design Engineer*	Hubbell
Dennis Emidy, State Safety Engineer*	Maine Department of Transportation
Callie Ewald, P.E., Geotechnical Engineering Manager	Vermont Agency of Transportation
Benjamin Foster, P.E., Deputy Chief Engineer*	Maine Department of Transportation
Joshua Hasbrouck, Civil Engineer, Bridge Program	Maine Department of Transportation
Dr. Mark Jen, P.E., S.E., Technical Manager	Michael Baker Engineering, Inc.
Garrett Kilfoyle, Assistant Engineer, Bridge Maintenance	Maine Department of Transportation
Brandon Kipp, Project Manager, Pavement Management Section	Vermont Agency of Transportation
John Kocur, Director of Engineering	Sperry Rail Service
Laura Krusinski, Senior Geotechnical Engineer	Maine Department of Transportation
James Lacroix, P.E., State Bridge Design Engineer	Vermont Agency of Transportation
Dr. Dongsheng Li, President	Advanced Manufacturing LLC
Alexander Mann, Hydrologist*	Maine Department of Transportation
Sam Maxim, Bridge Maintenance Engineer	Maine Department of Transportation
John Moran, Deputy Chief of Performance and Asser Management, Director of Asset Management	Massachusetts Department of Transportation
Andrew Mrockowski, Transportation Engineer	Connecticut Department of Transportation
Dale Peabody, Director, Transportation Research	Maine Department of Transportation
Michael Redman, Business Systems Manager, Concrete Quality Control Specialist, Bridge Program	Maine Department of Transportation
Karen Riemer, Asset Management Group	Connecticut Department of Transportation
Aaron Schwartz, Hot Mix Asphalt Engineer	Vermont Agency of Transportation
Gary Seider, Engineering Manager*	Hubbell
Rite L. Seraderian, P.E., FPCI, LEED AP, Executive Director	Precast/Prestressed Concrete Institute Northeast
Robert Skehan, Director, Office of Safety*	Maine Department of Transportation
Joseph Stilwell, Fabrication Engineer*	Maine Department of Transportation
Ken Sweeney, President*	AIT Bridges
Josh Tyler, Director of Operations*	Chittenden Solid Waste District (CSWD)
Nicholas Van Den Berg, Materials & Certification Manager*	Vermont Agency of Transportation
Nick Ward, P.E., Hydraulics Engineer, Project Delivery Bureau, Structures	Vermont Agency of Transportation
James Wild, Concrete Materials Manager	Vermont Agency of Transportation
Dr. Kathleen Wilson, P.E., Chief Civil Engineer	Rhode Island Department of Transportation
Mark Woolander, Pavement Engineer	Vermont Agency of Transportation
Hailing Yu, Civil Engineer	U.S. DOT Volpe Center

The following table identifies the 38 active collaborations and stakeholders and their contributions during the reporting period. (* indicates new project collaborators during this period)

Table 5: Research Project Collaborators		
Organization	**Location**	**Contribution**
AECOM*	Germantown, MD	Personnel
AIT Bridges, a division of Advanced Infrastructure Technologies	Brewer, ME	In-kind, collaborative research, personnel, facilities
American Concrete*	Auburn, ME	Financial support, facilities, collaborative research
Amtrak	Philadelphia, PA	Collaborative research, personnel
Argonne National Laboratory	Lemont, IL	Collaborative research, personnel
Chittenden Solid Waste District (CSWD)*	Williston, VT	Financial support, in-kind, facilities
City of Lowell	Lowell, MA	Collaborative research, facilities, personnel
Connecticut Department of Transportation	Newington, CT	Collaborative research, personnel
Connecticut Manufacturing Simulation Center	Storrs, CT	In-kind, facilities
Deep Foundations Institute	Hawthorne, NJ	Financial
Geophysical Survey Systems, Inc. (GSSI)*	Lowell, MA	Collaborative research, personnel
Intergraph Corporation	Madison, AL	In-kind
Jacobs Engineering	Herndon, VA	In-kind
Maine Department of Transportation	Augusta, ME	In-kind, collaborative research, financial, personnel, equipment
Massachusetts Department of Transportation	Boston, MA	Collaborative research, personnel
Metro-North Railroad Company	Bridgeport, CT	Collaborative research, facilities, personnel
National Center for Supercomputing Applications	Urbana, IL	In-kind
New Hampshire Department of Transportation	Concord, NH	Collaborative research, personnel
Oak Ridge National Laboratory	Oak Ridge, TN	In-kind, collaborative research, personnel, facilities
Omnisens*	Morges, Switzerland	In-kind, collaborative research, personnel, equipment
Polytec, Inc.	Hudson, MA	In-kind, collaborative research, personnel, equipment
Precast/Prestressed Concrete Institute Northeast (PCI-NE)	CT, MA, ME, NH, NY, RI, VT	Collaborative research, personnel
Rhode Island Department of Transportation	Providence, RI	Collaborative research, personnel
Saint-Gobain	Northborough, MA	In-kind, facilities, collaborative research, personnel, equipment
Sperry Rail Service	Shelton, CT	Collaborative research, in-kind, facilities, personnel
Superior Concrete	Auburn, ME	Financial, facilities, collaborative research
Texas Advanced Computing Center	Austin, TX	Facilities
The Nature Conservancy of Vermont	Montpelier, VT	Collaborative research, personnel

University of Connecticut	Storrs, CT	In-kind, collaborative research, personnel, facilities, financial
University of Maine	Orono, ME	In-kind, collaborative research, personnel, facilities, financial
University of Massachusetts Lowell	Lowell, MA	In-kind, collaborative research, personnel, facilities, financial
University of Rhode Island	Kingston, RI	In-kind, collaborative research, personnel, facilities, financial
University of Vermont	Burlington, VT	In-kind, collaborative research, personnel, facilities, financial
Vermont Agency of Transportation	Montpelier, VT	In-kind, collaborative research, personnel, financial
Vermont Department of Environmental Conservation	Montpelier, VT	Personnel
Vermont Technical College	Randolph Center, VT	Facilities, collaborative research, personnel
VHB*	Augusta, ME	Collaborative research
Western New England University	Springfield, MA	In-kind, collaborative research, personnel, facilities, financial

c. How have the results been disseminated?

Research results have been disseminated in a variety of ways throughout this reporting period. Research results are provided on each project's page on the TIDC Website through quarterly progress reports are available at https://www.tidc-utc.org/research/tidc-funded-projects-and-reports/. Further results were disseminated through journal articles, professional magazines, and meetings with New England State DOTs. Additionally, research findings are being disseminated in undergraduate and graduate courses at each university. Lastly, presentations from webinars and the 2020 Annual Conference are available on the TIDC YouTube page and the TIDC website.

d. What do you plan to do during the next reporting period to accomplish the goals?

Research

TIDC will continue to start new, high impact, relevant, and innovative research projects. During the next reporting period, the 2021 Request for Proposals was released in March 2021 and the awards are estimated to be announced in July 2021. The performance of current research projects will continue to be evaluated against the mission, goals, and objectives of TIDC.

Education & Workforce Development

TIDC personnel at UMaine plan to work with local school districts to implement transportation related activities created as part of the curriculum developed by the TIDC Program Coordinator. The team is working to created virtual kits that can be sent to students working remotely. TIDC personnel is also working with the University of Southern Maine's Robotics Track program to implement a bridge building competition aspect to the program. The competition is planned as a virtual event to be held in May. The live event typically brings over 200 middle school and high school students together in teams to compete in engineering challenges.

TIDC personnel at UMaine are continuing to work to create better partnerships with MaineDOT departments (including the HR, training, operations, and maintenance departments), industry leaders in

Maine, and Maine Community Colleges to create more opportunities for workforce development in the state and beyond.

In an effort to provide TIDC supported students with the opportunity to develop and refine soft skills needed when entering the transportation workforce, TIDC has created a monthly Showcase Presentation webinar. The Showcase Presentations will not only support student professional development, but with also help TIDC meet technology transfers and outreach goals. The following process will be followed each month: three universities will submit the title of the presentation and name(s) of student(s) presenting to allow Center to post the agenda on the TIDC website and Google calendar invitation. Students work with their PI to record a 15-minute presentation to be submitted to an internal review team comprised of peers and TIDC administration. The feedback is given to the student and their PI to allow the student to revise their pre-recorded presentation before the live webinar. On the day of the webinar, the pre-recorded presentation is played and is followed by a live Q&A session where the student has the opportunity to answer questions from the audience with the support of their PI. These monthly webinars are scheduled starting in April through the end of 2021.

TIDC faculty and principal investigators will continue to work with students on their research projects and add new students to replace those who have graduated. Additionally, research findings will continue to be disseminated in university classrooms and curriculum will be updated as new findings are presented.

Technology Transfer

To accomplish TIDC's technology transfer objectives identified in Section I. a., Technology Transfer, the following venues and mechanisms will be and/or continue to be employed: (1) a TIDC website and social media accounts that promote findings and opportunities for collaboration directly to the public; (2) the expansion of the 2021 TIDC Annual Conference on July 28-29, 2021 through early advertising and outreach activities in New England; (3) continued participation in regional transportation conferences; (4) a webinar series focused on sharing findings and engaging with industry professionals is scheduled to begin in the fall 2021; and (5) promotion of all market-ready technology transfer opportunities through industry/trade publications, the TIDC website, and social media accounts.

TIDC will continue to update the Center website and social media accounts to inform the public of TIDC activities, workshops, and research. Publications and papers will be submitted for conferences and publication in journals. TIDC principal investigators will attend conferences and workshops to disseminate research findings.

Collaboration

Principal Investigators and TIDC Management team members will continue to collaborate with state DOT/AOT representatives. All TIDC projects will continue to be supported by at least one Technical Champion (as described in Section I c – collaboration). Projects are encouraged to seek support from additional technical advisors in DOTs, government agencies, and industry leaders. These additional partnerships will increase the applicability of TIDC's research findings and create more opportunities for the adoption of findings in the region and beyond. Monthly management team meetings will continue and the Program Manager will visit each member university on a quarterly basis, once travel restrictions have been lifted. Additionally, the TIDC Advisory Board will be meeting in May 2021 to discuss the TIDC program and the expansion efforts for greater success. Also, to help with the goal of expanding the next TIDC Annual Conference for more collaboration opportunities, the dates and location for the 2021 conference have been selected (July 28-29, 2021 at UMaine with a hybrid model planned to allow for greater collaboration and attendance within the region).

II. PARTICIPANTS & COLLABORATING ORGANIZATIONS

a. What individuals have worked on the project?

In total, 46 principal investigators, faculty, administrators, and management team members and 78 students participated in TIDC research projects during the reporting period. As the projects progress, more student researchers will be added. All TIDC participants who were active during the reporting period are listed in the table below. (* Indicates students who graduated and received their degree during the reporting period.)

Table 7: Active Principal Investigators, faculty, administrators, students, and Management Team Members

Institution	Principal Investigators, Faculty, Administrators, and Management Team Members	Students
University of Maine	Dr. Habib Dagher, James Anderson, Dr. Warda Ashraf, Kathryn Ballingall, Dr. Keith Berube, James R. Bryce, Amanda Collamore, Dr. Bill Davids, Dr. Aaron Gallant, Dr. Douglas Gardner, Dr. Andrew Goupee, Dr. Yousoo Han, Dr. Hosain Haddad Kolour, Dr. Eric Landis, Dr. Roberto Lopez-Anido, Vu Phan, and Dr. Jonathan Rubin.	Madison Ala, Danilo Botero-Lopez, Sunil Bhandari, Justin Harris, Jeffrey Hollstien, SK Belal Hossen, Braedon Kohler, Sebastian Montoya, Andrew Schanck, Parry Seddiqi, Kelsey Weir, and Ryan Worster.
University of Connecticut	Dr. Ramesh Malla, Dr. Jiong Tang, Dr. Kay Wille, Dr. Jin Zhu, and Dr. Song Han, Dr. Wei Zhang, Dr. Nalini Ravishanker	Areej Althubaity, Omar Badawi, Ethan Beattie, Chris Boisvert-Cotulio, Alexander Biron*, Sudipta Chowdhury, Hernan Cortez Jr., Cydney-Alexis Delarosa, Celso de Oliveira, Suvash Dhakal, Santosh Dhakal, Alex Distelman, David Jacobs, Salaah Dean Kanaan, Seerut Mir, Paul Mooh Mooh Sr.,, Dominic Parciasepe, Kelly Quinn*, Bijaya Rai, Zheng Ren, Jeet Rosa, Andrew Schroder, Sachin Tripathi, Jason Trieu, Corey Walker, Jiachen Wang, Weiqi Wang*, Peng Wu, Yixin Yao, and Yang Zhang.
University of Massachusetts Lowell	Dr. Tzuyang Yu, Dr. Xingwei Wang, Dr. Susan Faraji, and Dr. Zhu Mao	Ahmed Alzeyadi*, Ronan Bates, Andres M. Biondi Vaccariello, Lidan Cao, Celso do Cabo, Harsh Gandhi, Xu Guo*, Jade Man, Nashire Peralta, Matt Southwick, Nick Valente, Sanjana Vinayaka, Jianing Wang, and Rui Wu.
University of Rhode Island	Dr. Aaron Bradshaw, Dr. K. Wayne Lee, Dr. Michael Greenfield, Dr. Sze Yang, Dr. George Veyera, Dr. Natacha Thomas, Dr. Christopher Hunter, and Dr. Farhad Atash	Austin DeCotis*, Mason Hyde*, Ali Sahraei Joubani, Nick Marchetti, and Stephan Zaets.
University of Vermont	Dr. Mandar Dewoolkar, Dr. Ehsan Ghazanfari, Dr. Ting Tan, Dr. Dryver Huston, Dr. Donna Rizzo, Dr. Arne	Maziar Foroutan, Ahmad Ghazanfari, Diarmuid Gregory, Zhuang Liu, Sienna Roberge*, and Rachel Seigel

	Bomblies, Dr. Hamid Ossareh, and Dr. Kristen Underwood	
Western New England University	Dr. Moochul Shin and Dr. ChangHoon Lee	Cameron Cox*, Abdoulaye Diallo*, Andrew Masullo, Nicholas Pantorno, Tiana Robinson, Georgii Tifaniuk, and Caleb Tourtelotte*.

b. What organizations have been involved as partners?

TIDC has received continued commitments of support and matching funds from 38 collaborators during this reporting period. The type of support provided by the collaborators varies from in-kind, financial, equipment, to supplies. In addition, many collaborators provide direct personnel links in research through Technical Champions. See table 5 on page 10 and table 6 on page 11 for an overview of the collaborators on TIDC research projects and what they have contributed.

c. Have other collaborators or contacts been involved?

Nothing to Report.

III. OUTPUTS

a. Publications, conference papers, and presentations:

The following table includes a list of the accepted and submitted papers and reports and presentations given during the reporting period:

Table 8: Publications, Conference Papers, and Presentations

Type	Title	Citation	Date	Status
Conference Paper	Stress-Strain Behavior of Steel Material from Two Old Railroad Bridges	de Oliveira, C., Tripathis, S., Castaldi, M., Malla, R., "Stress-Strain Behavior of Steel Material from Two Old Railroad Bridges." 33rd Rhode Island Transportation Forum. 2020.	10.30.2020	Presented
Conference Paper	Tensile Test and Stress-Strain Behavior from a more than Century Old Railroad Bridge	de Oliveira, C., Tripathi, S., Castaldi, M., and Malla, R., "Tensile Test and Stress-Strain Behavior from a more than Century Old Railroad Bridge." 2021 TRB Annual Conference. 2021	1.22.2021	Presented
Conference Paper	Monitoring and Dynamic Response of Two More Than Century Old Truss Railroad Bridges	de Oliveira, C., Tripathi, S., Castaldi, M., and Malla, R., "Monitoring and Dynamic Response of Two More Than Century Old Truss Railroad Bridges." 2021 International Bridge Conference. 2021.	01.2021	Accepted
Conference Paper	Large Scale 3D printed thermoplastic composite forms for precast concrete	Bhandari, S., Lopez-Anido, R., and Anderson, J., 5th International Conference & Exhibition on Thermoplastic Composites, ITHEC 2020 Virtual Edition, in proceedings p. 182, Bremen, Germany (2020).	10.13.2020-10.15.2020	Published

Conference Paper Abstract	Design and manufacture of precast concrete formwork using polymer extrusion based large scale additive manufacturing and post processing.	Bhandari S., Lopez-Anido R., Anderson, J., and LeBihan, A. ICAM 2021, ASTM International Conference on Additive Manufacturing, Nov 1-5, 2021	03.31.2021	Submitted
Conference Paper	Large-Scale Extrusion-Based 3D Printing for Highway Culvert Rehabilitation	Bhandari, S., Lopez-Anido, R.A., Anderson, J., and Mann, A., "Large-Scale Extrusion-Based 3D Printing for Highway Culvert Rehabilitation," SPE-ANTEC 2021 Conference Proceedings, May 10-14, 2021	3.2.2021	Accepted
Conference Paper	FDTD Simulation of Near-Field Scattering Pattern of a Surface Crack in Plate-like Structures for Optimal Inspection Angle Determination	https://www.spiedigitallibrary.org/conference-proceedings-of-spie/11592/115920V/FDTD-simulation-of-near-field-scattering-pattern-of-a-surface/10.1117/12.2593528.short?webSyncID=a5731747-75c7-52b6-5d04-2291e38a26c9&sessionGUID=844dc623-8995-e1d5-	3/22/2021	Accepted

b. Journal publications:

The following table includes a list of two TIDC journal publications and their status during the reporting period:

Table 9: Journal Articles and Publications

Title	Citation	Date	Status
Discrete Event Simulation Thermal Model for Extrusion-Based Additive Manufacturing of PLA and ABS	Bhandari, S., and Lopez-Anido, R.A., Materials, 12(21), 4985 (2020) (Open Access) https://doi.org/10.3390/ma13214985	11.5.2020	Published
A Study on Avalanches of Early Age Basalt Fiber Reinforced Concrete Beams During Flexure	Z. Liu, R.Worley, C.Giles, F.Du, M. Dewoolkar, D. Huston, T.Tan (2021), "A Study on Avalanches of Early Age Basalt Fiber Reinforced Concrete Beams During Flexure", Journal of Cleaner Production, 279, 123695.	10.01.2020	Published

c. Books or other non-periodical, one-time publications:

Nothing to Report

d. Other publications, conference papers, and presentations:

The following table includes a list of the articles and presentations that falls within the other publications, conference papers, and presentations section during the reporting period:

Table 10: Other Publications and Presentations				
Type	**Title**	**Citation/Description**	**Date**	**Status**
Magazine Article	AIT Bridge Contributes Composite Beams to Maine Bridge Replacement Project	Composites World Magazine https://www.compositesworld.com/news/ait-bridges-contributes-composite-beams-to-maine-bridge-replacement-project	01.08.2021	Published
Website Article	The Grist Mill Bridge in Hampden, Maine is Now Open	https://www.tidc-utc.org/2021/02/24/the-grist-mill-bridge-in-hampden-maine-now-open/	02.24.2021	Published
Magazine Article	New Composite Girder Technology Debuts in Maine's Grist Mill Bridge	Roads and Bridges Magazine https://www.roadsbridges.com/new-composite-girder-technology-debuts-maines-grist-mill-bridge	04.26.2021	Published
News Broadcast	First of Its Kind Bridge Could be a Model for Future of Infrastructure, Technology Developed in Maine	New Center Maine https://www.newscentermaine.com/article/tech/first-of-its-kind-bridge-could-be-a-model-for-future-of-infrastructure-technology-developed-in-maine/97-604767ab-1899-4f58-8fc1-f31de3f0fbcb	05.21.2021	Broadcast
News Article	A Brewer Company's New Technology will Stronger Bridges in Maine and Beyond	Bangor Daily News https://bangordailynews.com/2021/01/10/news/bangor/local-technologies-used-in-newly-opened-hampden-bridge-could-soon-be-used-worldwide/	1.10.2021	Published

e. Website(s) or other Internet site(s):

The following websites and social media sites are used to disseminate information about TIDC findings.
TIDC website: www.tidc-utc.org
Twitter: https://twitter.com/TIDCatUMaine
Facebook: https://www.facebook.com/TIDCatUMaine/
LinkedIn: https://www.linkedin.com/company/transportation-infrastructure-durability-center/
UMass Lowell's TIDC research page: https://www.uml.edu/Research/tidc/

f. Technologies or techniques:

Nothing to report.

g. Inventions, patent applications, and/or licenses:

Nothing to report.

IV. OUTCOMES

Researchers at the University of Maine worked with the MaineDOT, AIT Bridges, and the contractor to facilitate design and construction procedures for the novel technology. Provided rapid response to design questions/challenges that emerged during the construction of the bridge in Hampden. Live-load testing has been conducted onsite to document that the novel girder system exceeds Federal guidelines. The outcome of the research activities is the installation of the Grist Mill Bridge in Hampden, Maine, opened to traffic on December 23, 2020. The novel FRP composite tub girders are the first of its kind and are the first step toward achieving our 100 year life-span goal. The University of Massachusetts Lowell has developed an innovative monitoring and assessing system using fiber optic sensing technology. This new system was installed in the bridge girders before they were placed on site. The goal of the new system placement in the Grist Mill Bridge is to allow the research team to monitor the bridge girders from installation and identify when maintenance needs may arise before a visual inspection may detect the need. This, in turn, will help the MaineDOT to save maintenance costs involved with monitoring bridges.

V. IMPACTS

a. What is the impact on the effectiveness of the transportation system?

Nothing to report.

b. What is the impact on the adoption of new practices, or instances where research outcomes have led to the initiation of a start-up company?

Nothing to report.

c. What is the impact on the body of scientific knowledge?

Nothing to report.

d. What is the impact on transportation workforce development?

Nothing to report.

VI. CHANGES/PROBLEMS

a. Changes in approach and reasons for change:

TIDC Administration worked with the University of Rhode Island to replace the Institutional Lead. Dr. Aaron Bradshaw was selected as new Institutional Lead representing URI on the TIDC Management Team. TIDC recognizes that URI has a very strong reputation and high regard for delivering quality research results and believes the change in leadership at URI will help increase the collaboration of the University and RIDOT and will encourage high-quality, implementable research projects.

b. Actual or anticipated problems or delays and actions or plans to resolve them:

13 research projects requested and received internal no-cost extensions due to delays caused by COVID-19 restrictions.

c. Changes that have a significant impact on expenditures:

The impact of pandemic safeguards has had a significant effect on laboratory operations and field testing. TIDC is working to identify how these impacts have affected the financial status of the effected research projects and how to adjust budgets accordingly.

d. Significant changes in use or care of human subjects, vertebrate animals, and/or biohazards:

Nothing to report.

e. Change of primary performance site location from that originally proposed:

Nothing to report.

VII. SPECIAL REPORTING REQUIREMENTS

All TIDC projects are in compliance with Research Project Requirements (located in the Grant Deliverables and Reporting Requirements for 2016 and 2018 UTC Grants (Nov 2016, revised June 2018)) in regards to new research projects.