



TriDurLE

**National Center for Transportation
Infrastructure Durability & Life-Extension**

USDOT National University Transportation Center Progress Performance Report #3

Submitted to U.S. Department of Transportation
Office of the Assistant Secretary for Research and
Technology (OST-R)

Grant Number: 69A3551947137

Project Title: National Center for Transportation Infrastructure Durability
& Life- Extension (TriDurLE)

Center Director: Xianming Shi, Ph.D., P.E. Associate Professor
Department of Civil and Environmental Engineering
Washington State University
Pullman, WA 99163
xianming.shi@wsu.edu | 509-335-7088

Submission Date: April 30, 2021

DUNS: 04-148-5301

EIN: 91-6001108

Recipient Organization: Washington State University

Project/Grant Period: July 1, 2019 - September 30, 2023

Reporting Period Start Date: October 1, 2020

Reporting Period End Date: March 31, 2021

Report Term or Frequency: Semi-annual

Signature of Submitting Official:

Xianming Shi

TABLE OF CONTENTS

1. ACCOMPLISHMENTS	4
1.1 What are the major goals and objectives of the program?	4
Center Strategic Goals	4
Research	4
Leadership.....	4
Education and Workforce Development	4
Technology Transfer	4
Collaboration	5
Diversity	5
1.2 What was accomplished under these goals?	5
Research	5
Leadership.....	5
Collaboration	7
Education and Workforce Development	6
Diversity	8
Technology Transfer	7
1.3 What opportunities for training and professional development has the program provided?	9
1.4 How have the results been disseminated?	9
1.5 What do you plan to do during the next reporting period to accomplish the goals and objectives?	9
2. PARTICIPANTS AND COLLABORATING ORGANIZATIONS	10
2.1 Who has worked on the program?	10
Table 2.1 TriDurLE Site Directors.	10
2.2 What organizations have been involved as partners?	10
Table. 2. A list of organizations that have partnerships with TriDurLE.....	11
2.3 Have other collaborators or contacts been involved?	12
3. OUTPUTS	12
3.1 Publications, conference papers, and presentations	12
Publications.....	12
Technical Reports	15
Presentations.....	15
3.2 Website(s) or other internet site(s)	16
3.3 Technologies or techniques	16
3.4 Inventions, patent applications, and/or licenses	16
3.5 Other output	16
4. OUTCOMES	16
4.1 Increased understanding and awareness of transportation issues	16

4.2 Passage of new policies, regulation, rulemaking, or legislation _____	16
4.3 Increases in the body of knowledge _____	16
4.4 Improvement of existing techniques, practices, technologies _____	16
4.5 Enlargement of the pool of trained transportation professionals _____	16
4.6 Incorporation of new techniques, practices, technologies _____	16
5. IMPACTS _____	17
5.1 What is the impact on the development of the principal discipline(s) of the program? _____	17
5.2 What is the impact on other disciplines? _____	17
5.3 What is the impact on the development of transportation workforce development? _____	17
5.4 What is the impact on physical, institutional, and information resources at the university or other partner institutions? _____	17
5.5 What is the impact on technology transfer? _____	17
5.6 What is the impact on society beyond science and technology? _____	17
6. CHANGES/PROBLEMS _____	18
6.1 Changes in approach and reasons for change _____	18
6.2 Actual or anticipated problems or delays and actions or plans to resolve them _____	18
6.3 Changes that have a significant impact on expenditures _____	18
6.4 Significant change in use or care of animals, human subjects, and/or biohazards _____	18
6.5 Changes of primary performance site location from that originally proposed _____	18
6.6 Additional information regarding products and impacts _____	18
7. SPECIAL REPORTING REQUIREMENTS _____	18
APPENDIX _____	19

1. ACCOMPLISHMENTS

1.1 What are the major goals and objectives of the program?

The partnerships underlying this National UTC are based on the shared vision of “cost-effective innovations and holistic solutions to enhance multimodal infrastructure durability.” TriDurLE will conduct multidisciplinary and multimodal research, education and workforce development, and technology transfer related to this vision, and will directly support the USDOT’s strategic goal of infrastructure durability and life-extension while providing secondary benefits for other relevant strategic goals such as safety, mobility, and environmental sustainability.

Center Strategic Goals

The National UTC TriDurLE is concerned with the following strategic goals:

- Facilitating innovations in data modeling/management, analytical tools, and decision-making related to infrastructure durability and life-extension.
- Enhancing understanding of transportation infrastructure performance and asset management via condition monitoring and remote sensing.
- Extending the service life of transportation infrastructure and addressing durability issues through new materials and technologies and best practices.
- Leading the way in education, workforce development, capacity building, and technology transfer.

Research

The research activities of the National UTC TriDurLE are grouped into six interrelated thrust areas as follows, which will be supplemented by education and technology transfer activities.

- Management: Asset management and performance management for enhanced durability and life-extension of transportation infrastructure.
- Monitoring: Condition monitoring, remote sensing, and the use of GPS for enhanced durability and life-extension of transportation infrastructure.
- Addressing corrosion of transportation infrastructure.
- Addressing aging and other materials-related durability distresses of transportation infrastructure by new materials, technologies, and construction methodologies.
- Addressing natural hazards and extreme events that threaten the durability and service life of transportation infrastructure.
- Intervention and rehabilitation of transportation infrastructure through advanced materials, technologies and construction methodologies.

Leadership

The TriDurLE team is nationally and internationally recognized for contributions to the field of infrastructure durability and for its deployment of effective solutions to critical, real world transportation challenges. Through this UTC grant, the Consortium plans to build on its demonstrated experience to support, encourage and mentor future leaders in the field of transportation, with a cross-disciplinary approach to infrastructure durability.

Education and Workforce Development

TriDurLE will provide a range of education and workforce development (E&WD) opportunities for students and professionals across the nation to contribute to a skilled, diverse, informed and practice-ready transportation workforce. The E&WD program will build on the success of existing programs at the Consortium universities, starting from K-12. The program will promote creative and multidisciplinary problem solving and exposure to a myriad of experiences, serving to attract, educate, and train future and existing transportation professionals with the know-how to undertake and implement innovative projects. The outreach initiatives will particularly focus on recruiting underrepresented minorities into transportation and other STEM fields.

TriDurLE will also support career-building activities that facilitate student transition from school to the workplace by offering enhanced student research opportunities, research seminars, guest speakers, professional conference travel and other professional networking opportunities.

Technology Transfer

TriDurLE will maintain an ongoing technology transfer (T2) program to ensure research results are made available to potential users in a form that can be implemented, utilized, commercialized, or otherwise applied quickly and to the widest possible audience. The goals of T2 activities by TriDurLE will mainly include:

- Knowledge dissemination, to inform stakeholders in various aspects of transportation infrastructure

durability and life-extension, including policy makers, public decision makers, transportation infrastructure professionals, industry partners, researchers and technology developers, and the general public

- IP implementation, to move the IP from research and development phases towards adoption by practitioners and to spur implementation by industry
- Brand awareness building, to increase the visibility of TriDurLE researchers, outputs, and outcomes and to broaden the potential impacts of TriDurLE activities

Collaboration

Many of the consortium members have an extensive history of collaborative relationships at a variety of technical, fiscal, and administrative levels. Across all its activities—from conducting pooled fund studies to hosting technology transfer events—TriDurLE will seek to work with partners from all sectors.

Diversity

TriDurLE is committed to an explicit policy and active program of engaging diverse and underrepresented groups, with the goal of increasing their interest and participation in STEM disciplines and awareness of careers in the transportation fields. In order for the transportation workforce to reflect the diversity of the national workforce pool, TriDurLE will continue to pursue the development of innovative programs to encourage new entrants, particularly those from groups currently underrepresented in the field, including women, minorities and those with disabilities.

1.2 What was accomplished under these goals?

Research

The 26 year-one research projects have made reasonable progress given the constraints caused by COVID-19. Some laboratories were closed for periods of time for quarantines and some have since been restricted to comply with COVID rules for distancing. Furthermore, the University of Mississippi site director passed away due to COVID-19, halting the research from that consortium member. TriDurLE is currently working with the University of Mississippi for a replacement of principal investigator (PI) for the Year one project funded at that site.

The appendix contains the list of year-one projects that have been funded with respect to each member university. During this reporting period, the request for proposals for year-two projects was developed and distributed to the faculty members at the 10 TriDurLE sites and year-two research proposals are currently being submitted.

No-cost time extensions may be needed for some year-one projects in light of the delays caused by the limited access to laboratory facilities and potential difficulties in student recruitment. *Washington State University* Year-one projects are ongoing but behind schedule due to COVID-related challenges. *South Dakota State University* reported that approximately 60% of its year-one project were completed and the team has received additional funding from Precast/Prestressed Concrete Institute to support a graduate student for two years. *Missouri University of Science & Technology* reported that some preliminary results of its research were shared with state DOTs (e.g., Missouri, Kansas, and Colorado DOTs) to potentially establish further research opportunity and test sections. *University of Utah* reported that a new research initiative titled “Development of Holistic Methodologies for Improving Asphalt Mix Durability” was started with a collaboration between Texas A&M University, Missouri S&T, and the University of Utah. The other research project carried out by the University of Utah and the *University of Denver* will further three TriDurLE thrust areas: (i) Area 3: addressing corrosion of transportation infrastructure assets, (ii) Area 5: addressing natural hazards and extreme events that threaten the durability and service life of transportation infrastructure, and (iii) Area 6: maintenance intervention and rehabilitation of transportation infrastructure through advanced materials, technologies, and construction methodologies.

Case Western Reserve University reported that one of its proposed Year-two research projects will (a) effectively and comprehensively measure network resilience at multiple transportation management levels (i.e., the enterprise, network, and project levels) and (b) provide cost-effective decisions on both pre- and post-hazard resilience-enhancing strategies and optimal combinations of inspection/monitoring techniques. This goal is well aligned with the vision of TriDurLE “cost-effective innovations and holistic solutions to enhance multimodal infrastructure durability.” The proposed research has a potential for integrating all the six thrust areas of TriDurLE into a holistic resilience-based asset management framework.

Leadership

TriDurLE researchers have led in a number of capacities during this reporting period as committee chairs, panelists, editors, Associate Editor or Editorial Board Member of scholarly journals, project managers, awardees for outstanding performance, etc. Following is a list of leadership activities conducted by

consortium members during this reporting period:

Washington State University

- Dr. Xianming Shi, Founding Editor-in-Chief, [Journal of Infrastructure Preservation & Resilience](#), since 2019; Association Editor of Journal of Nondestructive Evaluation, since 2020; Editorial Board of [International Journal of Transportation Science and Technology](#), since 2018; Co-Editor, Special Issue: [Intelligent Concrete, New Functionalities and Nanotechnology](#), Frontiers in Materials journal; Co-Editor, Special Issue: [Eco-Friendly and Energy-Saving Cementitious Materials](#), Advances in Civil Engineering journal
- Dr. Pizhong Qiao, Associate Editor for the Journal of Engineering Mechanics, Journal of Aerospace Engineering, and Structural Health Monitoring.
- Dr. Ji Yun Lee, Editorial Board of Reliability Engineering and Resilience, since 2020

Case Western Reserve University

- Dr. Xiong (Bill) Yu, Chair, ASCE Geo-Institute Committee on Engineering Geology and Site Characterization
- Dr. Yue Li, Chair of Technical Council on Life-Cycle Performance, Safety, Reliability and Risk of Structural Systems, Task Group 3 (TG3): Risk Assessment of Structural Infrastructure Facilities and Risk-Based Decision Making (2018 - 2022)

Missouri University of Science & Technology (S&T), Dr. Jenny Liu

- Session Chair, 2021 Regional Conference on Permafrost and 19th International Conference on Cold Region Engineering, October 24–29, 2021(virtual).
- Discipline - Co-chair, Technical Committee, 2021 World Transportation Convention, June 15-19, 2021.
- Chair, Scientific Committee, 5th International Conference on Transportation Infrastructure and Materials, 2021.Diversity
- Panelist, Women in STEM, Missouri S&T, Jan 2021
- Panelist, Academy of Civil Engineers "Fall Networking Event", Missouri S&T, November 2020
- Appointed to ASCE Bituminous Materials Committee Chair, 2021-2023

Dr. Xiong Zhang, Missouri S&T received the 2020 Faculty Research Award; Chair, ASCE Geo-Institute Shallow Foundation Committee, since 2020; Association Editor of ASCE Journal of Cold Regions Engineering, since spring 2020; ASCE G-I Task Force on Risk Based Geotechnical Design Code.

Dr. XB Hu, Missouri S&T, was appointed to be an At-Large Member of the TRB Committee Research Coordinator (CRC) Leadership Council (CRCC), Jan 2021; Associate Editor, [International Journal of Transportation Science and Technology](#), since 2020; Outstanding Associated Editor Award from the International Journal of Transportation Science and Technology, Jan 2021

University of Utah: Through the leadership of the University of Utah two members of the TriDurLE Advisory Board were invited and have accepted the invitation and are now on the board: Carmen Swanwick who is a UDOT Bridge Engineer, and Ben Sadawi who is the Technical Services Manager for MMFX Technologies. Dr. Christian Carloni served as: Member of the Editorial Board of Journal of Composites for Construction (ASCE); Voting Member of ASCE/ACI Joint Committee 446 on Fracture Mechanics; Voting Member of ACI Committee 549 on Thin Reinforced Cementitious Products; Voting Member of ASTM D30.10 and ASTM C09 Technical Committee (Composite Materials).

Dr. Francisco Presuel of Florida Atlantic University serves as vice-chair for TEG 053X for AMPP (previously NACE). He also serves as Document Project Manager for TR21429 (State-of-the-Art Report, Reinforced Concrete: Corrosion-Resistant Reinforcement) under SC-12 AMPP.

Dr. Yail Jimmy Kim served as President of the Bridge Engineering Institute (BEI) and Chair of American Concrete Institute Committee 440I (FRP-Prestressed Concrete). He also participated in handling and editing manuscripts for the Journal of Advances in Structural Engineering and chaired the American Concrete Institute (ACI) Committee 440I during the ACI Spring Convention and highlighted the importance of composite applications for bridge construction.

Dr. Mostafa Tazarv of South Dakota State University organized a session titled “Emerging Connections for Accelerated Bridge Construction (ABC)” for the ACI fall 2020 convention, on Oct. 25, 2020.

Dr. Mohamad Ashour of Alabama A&M University is serving as a member of the Seismic and Lateral Loads Committee, Deep Foundation Institute (DFI).

Education and Workforce Development

Washington State University has partially supported two postdoctoral research associates, seven Ph.D.

students, and three M.S. students (Stacia Bell, Zachary Quesnel, Sean McGuinness). At least six undergraduate students have been involved with TriDurLE related research. Some of the student accomplishments are listed as follows:

- Zhipeng Li, Outstanding Research Assistant Award, selected by the Department of Civil & Environmental Engineering, Washington State University, 2021
- Zhipeng Li, Waheed Uddin Outstanding Graduate Student Award, 2nd Place, selected by the National Center for Transportation Infrastructure Durability & Life-Extension, 2020.
- Mehdi Honarvar Nazari, Taekil Oh, Alexander C. Ewing, Deborah A. Okon, Yan Zhang, Brandon Avalos, Eisa Alnuaimi, Eden A. Havens, and Xianming Shi, 2020 High Value Research – Maintenance, Management & Preservation Supplemental Award, American Association of State Highway and Transportation Officials (AASHTO)
- Mehdi Honarvar Nazari, Dissertation Award winner, for both the Department of Civil & Environmental Engineering and the Voiland College of Engineering and Architecture, Washington State University, 2021
- Mehdi Honarvar Nazari, J.F. Orsborn scholarship in Civil Engineering for Graduate School, 2021
- Mehdi Honarvar Nazari, Richard Perteet Endowment Scholarship, 2020
- Yan Zhang, University Transportation Center (UTC) Student of the Year, awarded by the U.S. Department of Transportation, 2020.
- Ayumi Manawadu, Outstanding Teaching Assistant Award, selected by the Department of Civil & Environmental Engineering, Washington State University, 2021; Winner of the 3-Minute Thesis Competition at WSU, 2021

Other consortium universities reported student research participation and accomplishments as follows:

- Jun Liu, PhD student at Missouri S&T, received first place IACIP Outstanding Graduate Student Award, Jan 2021
- Anyou Zhu and Hanli Wu, PhD students at Missouri S&T, received Second Place and Third Place IACIP Best Poster Awards, Jan 2021
- Kazi Hoque of Florida Atlantic University completed his PhD (the last term of his studies was partially funded by TriDurLE) in Ocean Engineering during Fall/2020.
- At the University of Colorado Denver, one post-doc and five PhD students fully and partially participated in research projects. Although the development of workforce was not at the level of an ordinary situation because of the pandemic, these researchers were reasonably trained.
- South Dakota State University currently supports two M.S. students (Evan Greenway in Civil Engineering, Youjeong Jang in Computer Science) who are involved in topics related to bridge engineering. Mr. Kallan Hart has received the PCI Dennis R. Mertz Bridge Research Fellowship and will start working on the project as soon as the TriDurLE Year Two proposal review is complete.
- Abdulah Al Mamum joined the University of Utah in January 2021 as a Ph.D. Student. Sayal Shrestha joined the University of Utah in January 2021 as a Ph.D. Student.

Research outcomes on structural reliability formulation and updating will be included in a graduate course ECIV 426 Probabilistic Analysis at CWRU. Research outcomes on decision-making with additional information will be introduced in a senior-level & graduate-level course CE 405/505 Decision-Making for Sustainable and Resilient Infrastructure at WSU

Technology Transfer

<https://TriDurLE.wsu.edu/> provides information on Center activities as well as links to our quarterly newsletter. The Center organized/hosted monthly webinars that were recorded and posted online and periodically posted announcements (e.g., academic conference) and news items (e.g., new publications or presentations). The journal articles, conference papers, technical reports and presentations detailed in Section 3.2 also contribute to the mission of technology transfer. Furthermore, Dr. Shi's team at WSU has filed a number of patent applications in this reporting period as follows:

- Shi, X., Zhong, J. Method to nano-engineer interfaces in cementitious composites. Provisional Patent on Feb. 12, 2021.
- Shi, X. Biologically-Derived Deicer. Non-Provisional patent filed on Feb. 10, 2021.
- Shi, X., Du, S. Abrasion Resistant Cementitious Material as a Protective Coating for Various Surfaces. Provisional Patent on Oct. 21, 2020.

Collaboration

See Section 2 for details. TriDurLE researchers have expanded their collaboration network with state and

local government agencies, private sector, and advisory board members, as well as research collaboration between universities. For example, Washington State University (WSU) initiated discussions with stakeholders from public and private agencies about the appropriate business model to use for a proposed industry partnership advisory board. The WSU team has also worked closely with Idaho Transportation Department (ITD) on a research project jointed sponsored by TriDurLE and ITD. The TriDurLE Director, Dr. Xianming Shi, has discussed with Springer Nature about potential collaboration mechanisms such as co-sponsorship of a workshop by TriDurLE and Journal of Infrastructure Preservation & Resilience (for which Dr. Shi is the Founding Editor-in-Chief). Dr. Ji Yun Lee has been conducting research funded by Washington State Department of Transportation (WSDOT) and our Regional UTC PacTrans in collaboration with researchers at University of Washington, while collaborating with Case Western Reserve University on a TriDurLE Year-one research project.

University of Utah has developed extensive collaboration between Texas A&M University, Missouri S&T, and the University of Utah. Such collaboration will ensure that the findings, products, and technology are applicable to a broader industry across the country. In this reporting period, large-scale tests to be conducted at the University of Utah have been discussed with the University of Denver. These tests will benchmark the actual seismic performance of bridge bents constructed with ABC technologies, including the consequences of corrosion damage on the performance. The work at the University of Colorado Denver in collaboration with Yamaguchi University will focus on advanced modeling and laboratory-scale testing to fundamentally understand the initiation and progression mechanisms of chloride-induced corrosion in ABC (accelerated bridge construction) columns to quantify risk and uncertainties, which are required to develop performance-based design guidelines. South Dakota State University has established partnerships with industry such as PCI through collaborative and multidisciplinary projects and has engaged members of different transportation agencies in our projects mainly as the members of the advisory committees.

Diversity

In an effort to improve awareness of the field of transportation and more specifically the work in areas related to transportation infrastructure durability and life-extension to diverse audiences, the TriDurLE center has implemented intentional efforts at all levels from proposal submissions to outreach and engagement. For proposal submission for 2021, principal investigators are required to submit a diversity/outreach plan, indicating their intentional efforts throughout the year to increase diversity in their laboratories and classrooms. During the fiscal year, the TriDurLE diversity team will gather demographics of research participants, students in courses taught by researchers that relate to the topic of the center, and participants of monthly webinars in order to access the population we are engaging and develop mechanisms to increase the diversity of the population.

To promote diversity within TriDurLE, the Center has developed funding opportunities for faculty and staff at consortium universities who travel to promote diversity. The Waheed Uddin Diversity Travel Grants will provide funding up to \$1500 per award each year to four TriDurLE consortium university faculty or staff (postdoctoral researcher, engineer, coordinator, etc.) who have participated in presentations/activities to enhance diversity. Travel grants have also been established for students, providing up to \$750 per award (for up to 8 students) who attend activities to enhance professional development or academic goals. The Waheed Uddin Diversity Graduate Research Fellowship (GRF) has also been established to increase access and opportunities to graduate education for students from under-represented and under-served communities. The fellowship will fund up to three students per year for diverse students conducting relevant research to the TriDurLE strategic priorities

To increase the number of diverse undergraduate and graduate students engaged in research at the collaborating institutions in the TriDurLE UTC, consortium member Tennessee State University will provide funding for students to collaborate on other researchers' projects. TSU will either support a student conducting summer research at one of the institutions, or have a student conducting components of the research at the TSU campus during the semester or summer to support the efforts at another institution.

Following are consortium university diversity reports:

- Catherine Armwood gave a Black History Month presentation at Harpeth Hall, an all-girl's school in Nashville, titled, "Service: The Path to Success" on February 8, 2021
- In celebration of Women's History Month, TriDurLE's March webinar featured speaker Carmen Swanwick of the Utah Department of Transportation to talk about insights into her career as a bridge engineer.

- In collaboration with Vanderbilt University and University of Memphis, TSU organized and executed Tennessee Department of Transportation's first ever Innovation to Implementation Forum and Peer-Exchange April 5-6, 2021.
- TriDurLE director of diversity Catherine Armwood will be a panelist at the Women Transportation Seminar (WTS) Virtual Annual Conference May 10-14, 2021 titled "Secrets to Retaining Diverse Engineering Students"
- TSU was awarded a National Summer Transportation Institute from TDOT for summer 2021. The program will target high school students grades 9-12 and will involve two, two-week camps. The first two weeks of camp will be in-person, and will target 20 students and the second two-week session will be virtual with a target population of 50 students. The program will include approximately four days dedicated to transportation materials and infrastructure such as bridges and dams.
- One MS thesis student and two undergraduates in engineering at Washington State University are from an under-represented group in.
- Florida Atlantic University has been named a Hispanic serving institution and will continue recruiting minority students to work on projects.
- One female was involved in the research at UC Denver. When the pandemic situation gets better, an active recruitment plan will be carried out.
- University of Utah: Two female students are currently participating at the University of Utah to assist with the experimental campaign.
- Case Western Reserve University: Students with different ethnic backgrounds are involved in this project throughout the research activities towards Objectives 1, 2 and 3, including field inspection data collection, reliability theoretical model formulation, road-network-performance simulation model development, and Bayesian-network-based resilient assessment model development.

1.3 What opportunities for training and professional development has the program provided?

The TriDurLE monthly webinars have been promoted via multiple channels to professional groups likely interested in transportation infrastructure preservation and life-extension. These are open to the public, particularly of value to the local and state transportation agencies, as well as to industry practitioners and researchers. These monthly Invited Speaker Series Webinars are led by leading experts in the field. Most of the webinars are recorded and posted on our website, and Professional Development Hour Certificates are available upon request.

- October 2020, Dr. Zhongren Wang of Caltrans spoken on "Implementing a Pavement Management System in California."
- November 2020, Dr. Chris Pantelides of University of Utah spoke on "Axial Compression Capacity of Concrete Columns Reinforced with Corrosion-Resistant Hybrid Reinforcement."
- February 2021, Dr. XB Hu of Missouri University of Science & Technology spoke on "Development and Testing of Autonomous Vehicle Technology for Transportation Infrastructure Maintenance."
- March 2021 Carmen Swanwick of the Utah Dept. of Transportation and a TriDurLE advisory board member spoke on "Bridge Engineering: Insights into a Career as A Bridge Engineer."
- Several consortium universities also reported training students in laboratories to participate in TriDurLE research projects.

TriDurLE has established a Diversity Graduate Research Fellowship to provide one-year funding for diverse students pursuing education in TriDurLE initiatives.

1.4 How have the results been disseminated?

As detailed in Section 3, TriDurLE researchers and students have disseminated the results of their work through journal publications, conference papers, technical reports, and presentations at professional conferences or workshops.

1.5 What do you plan to do during the next reporting period to accomplish the goals and objectives?

The following tasks are planned to accomplish the goals and objectives of TriDurLE.

- Hold monthly meetings with executive committee (Site Directors); and hold quarterly Zoom Meetings w/ fiscal staff members and outreach coordinator
- Plan for the 2021 Annual Symposium of this National UTC, likely to be held in late Fall 2021.
- Continue efforts in research, leadership, education, workforce development, diversity, and technology transfer, on behalf of the National UTC TriDurLE.
- Continue to explore opportunities of collaboration to pool resources and expand the scope of previous success. Specifically, continue to work with State DOTs to develop the scope of a Transportation Pooled Fund (TPF), Consortium for Durable Roads and Bridges (CDuRB) and a companion fund (to engage private-sector stakeholders); these funding mechanisms aim to leverage the existing TriDurLE resources and expertise and enhance the impacts and long-term sustainability of the National UTC funding support. Continue to develop a diverse collaboration network with different state and local government agencies, private sector, educational and professional organizations (and their student chapters), other university transportation centers (UTCs), FHWA offices, and universities in the U.S. and abroad. Expand our collaboration with the Journal of Infrastructure Preservation & Resilience (JIPR) and Bridge Engineering Institute (BEI).
- Maintain a robust website and publish a quarterly e-newsletter
- Work with partners to pursue commercialization and licensing opportunities
- Continue to update the website, Facebook, Twitter, and YouTube pages, particularly those related to publications, presentations, monthly webinars, collaborations, and events/activities related to diversity, leadership, collaboration, education, workforce development, or technology transfer.

2. PARTICIPANTS AND COLLABORATING ORGANIZATIONS

2.1 Who has worked on the program?

In addition to the Site Directors listed in Table 2.1, all researchers are listed on our website at <https://tridurle.wsu.edu/researchers/>

Table 2.1 TriDurLE Site Directors.

University	Name	Contribution to Program
Alabama A&M	Mohamad Ashour	Site Director
Case Western Reserve University	Xiong (Bill) Yu	Site Director
Florida Atlantic University	Francisco Presuel-Moreno	Site Director
Missouri University of Science & Technology	Jenny Liu	Site Director, TriDurLE Director for Research
South Dakota State University	Mostafa Tazarv	Site Director
Tennessee State University	Catherine Armwood	Site Director, TriDurLE Director for Diversity
Texas A&M University	Dan Zollinger	Site Director
University of Colorado Denver	Yail Jimmy Kim	Site Director
University of Mississippi	TBA	Site Director
University of Utah	Chris Pantelides	Site Director
Washington State University	Xianming Shi	Center Director and Site Director

2.2 What organizations have been involved as partners?

Table 2 provides a list of organizations that have partnerships with TriDurLE.

Table 2. A list of organizations that have partnerships with TriDurLE.

Organization Name	Type / Location	Partners Contribution to Project				
		Financial Support	In-kind Support	Facilities	Collaborative Research	Personnel Exchanges
Alabama A&M University	Government /Alabama	X	X	X		
Denver Streets Partnership	Government/ Colorado		X		X	
Libyan North American Scholarship Program	Government/ Canada		X			
Case Western Reserve University	Government/ Ohio		X	X	X	X
Colorado DOT Accelerated Bridge Construction (ABS)	Government/ Colorado		X		X	
Emulsion Products, Inc.	Industry					X
Florida Atlantic University	Government /FL		X	X		X
Florida DOT	Government/FL	X				
Geneva Rock Products	Industry/Utah		X		X	
Illinois DOT Bureau of Materials	Government/ Illinois		X			
Kansas DOT			X			
KeraKoll Group	Industry/Italy		X			X
Kokosing Materials, Inc.	Industry/Ohio		X			
Missouri S&T	Government/ Missouri		X	X	X	X
Missouri DOT	Government/ Missouri	X			X	X
Missouri, City of Rolla	State/Missouri					X
MYKatikrete	Industry/India					
Northeast Forestry University	Government/ China	X			X	X
Ruregold SRL	Industry/Italy		X			
SBIR/STTR	Federal					
Sika USA	Industry		X		X	
SNS Dempers	Industry/Utah		X			
South Dakota State University	Government/ South Dakota	X	X	X		

Tencate North America	Industry	X			X	
Texas A&M University	Government/Texas		X	X	X	
The Polytechnic University of Milan	Government/Italy		X		X	
University of Maryland, College Park	Government/Maryland				X	
University of Mississippi	Government/Mississippi		X	X		
University of Utah	Government/Utah		X	X	X	X
Washington State University	Government/Washington	X	X	X	X	X
Washington State DOT	Government/Washington	X	X			
Idaho Transportation Department	Government/Idaho	X				
Simpson Strong-Tie, Co.	Industry/California		X			

2.3 Have other collaborators or contacts been involved?

- Inspecting and Preserving Infrastructure through Robotic Exploration (INSPIRE) UTC
- Hughes Brothers (currently Dow Corning) and are waiting for their response to initiate collaboration.
- City and County of Denver
- Bike Denver
- Bicycle Colorado
- Walk Denver
- Colorado Cross-Disability Coalition
- Groundwork Denver Community/Environmental Organization
- All in Denver Affordable Housing Organization
- American Heart Association
- Precast/Prestressed Concrete Institute (PCI)
- Journal of Infrastructure Preservation & Resilience (JIPR, by Springer Nature)
- Bridge Engineering Institute (BEI)
- Alabama Department of Transportation (ALDOT)
- Seal/No Seal Group
- Crafc0, Inc.
- Dow Chemical Company

3. OUTPUTS

3.1 Publications, conference papers, and presentations

Publications

1. He, J. , Shi, X. Laboratory Assessment of a Self-healing System for Early-Age Durability Benefits to Cementitious Composites. *Journal of Building Engineering*, 2021, in press.
2. Du, S. , Ge, Y., Shi, X. Multi-phase Sphere Modeling of High-Volume Fly Ash Concrete: Freezing-thawing Performance. *ASCE Journal of Materials in Civil Engineering*, 2021, DOI: [10.1061/\(ASCE\)MT.1943-5533.0003813](https://doi.org/10.1061/(ASCE)MT.1943-5533.0003813).
3. Li, Z. , Fei, M., Huyan, C., Shi, X. Nano-Engineered, Fly Ash-Based Geopolymer Composites: An Overview. *Resources, Conservation & Recycling*, 2021, 168, 105334. DOI:

- [10.1016/j.resconrec.2020.105334](https://doi.org/10.1016/j.resconrec.2020.105334).
4. Tang, Z., Li, Z., Fan, L., Gong, J., Zhong, J., Shi, X. Effect of Surface Tension, Foaming Stabilizer, and Graphene Oxide on the Properties of Foamed Paste. *Journal of Nanoscience and Nanotechnology*, 2021, 21(5), 3123–3133. DOI: [10.1166/jnn.2021.19282](https://doi.org/10.1166/jnn.2021.19282).
 5. Lei, Z., Li, Z., Zhang, X., Shi, X. Durability of CFRP-Wrapped Concrete in Cold Regions: A Laboratory Evaluation of Montmorillonite Nanoclay-Modified Siloxane Epoxy Adhesive. *Construction and Building Materials*, 2021, 290, DOI: [10.1016/j.conbuildmat.2021.123253](https://doi.org/10.1016/j.conbuildmat.2021.123253).
 6. Liu, K., Li, T., Wu, C., Jiang, K., Shi, X. Bamboo Fiber Has Engineering Properties and Performance Suitable as Reinforcement for Asphalt Mixture. *Construction and Building Materials*, 2021, 290, DOI: [10.1016/j.conbuildmat.2021.123240](https://doi.org/10.1016/j.conbuildmat.2021.123240).
 7. Nazari, M.H., Jiang, Y., Shi, X. Effects of Ferrous Alloy Type, Beetroot Juice, Deicer Type and Concentration on Early-Stage Corrosion Behavior of Buried Pipes. *ASCE Journal of Materials in Civil Engineering*, 2020, 32(10), DOI: [10.1061/\(ASCE\)MT.1943-5533.0003379](https://doi.org/10.1061/(ASCE)MT.1943-5533.0003379).
 8. Zhao, D., Wang, Z., Lu, S., Shi, X. An Amidoxime-Functionalized Polypropylene Fiber: Competitive Removal of Cu(II), Pb(II) and Zn(II) from Wastewater and Subsequent Sequestration in Cement Mortar. *Journal of Cleaner Production*, 2020, 274, DOI: [10.1016/j.jclepro.2020.123049](https://doi.org/10.1016/j.jclepro.2020.123049).
 9. Cong, X., Lu, S., Gao, Y., Yao, Y., Elchalakani, M., Shi, X. Effects of Microwave, Thermomechanical and Chemical Treatments of Sewage Sludge Ash on Its Early-Age Behavior as Supplementary Cementitious Material. *Journal of Cleaner Production*, 2020, 258, DOI: [10.1016/j.jclepro.2020.120647](https://doi.org/10.1016/j.jclepro.2020.120647).
 10. Tang, Z., Qiu, Z., Lu, S., Shi, X. Functionalized Layered Double Hydroxide Applied to Heavy Metal Ions Absorption: A Review. *Nanotechnology Reviews*, 2020, 9, 800-819. DOI: [10.1515/ntrev-2020-0065](https://doi.org/10.1515/ntrev-2020-0065).
 11. Lim, J., Bahadori, A., Wen, H., Littleton, K., Corley, P., & Muhunthan, B. (2021). Feasibility of 9.5-mm Stone Matrix Asphalt for Thin Lift Overlays in Washington State. *Journal of Materials in Civil Engineering*, 33(4), 04021044.
 12. Li, X., Zhang, K., Bahadori, A., & Muhunthan, B. (2020). Modification of Asphalt Materials to Resist Studded-Tire Wear on Pavements. *Journal of Materials in Civil Engineering*, 32(3), 04020023.
 13. Amarasiri, S., & Muhunthan, B. (2020). Evaluating the effectiveness of pavement preventive-maintenance treatments in mitigating longitudinal cracks in wet-freeze climatic zones. *Journal of Transportation Engineering, Part B: Pavements*, 146(2), 04020014.
 14. Abbasi, B., Muhunthan, B., Salehinia, I., & Zbib, H. M. (2020). Nanoscale Stick-Slip Behavior of Na-Montmorillonite Clay. *Journal of Engineering Mechanics*, 146(12), 04020138.
 15. Amarasiri, S., & Muhunthan, B. (2020). Evaluating Cost Effectiveness and Optimal Timing of Pavement Preventive-Maintenance Treatments in Wet-Freeze Climates. *Journal of Transportation Engineering, Part B: Pavements*, 146(3), 04020050.
 16. Wu, S., Tahri, O., Shen, S., Zhang, W., & Muhunthan, B. (2021). Environmental impact evaluation and long-term rutting resistance performance of warm mix asphalt technologies. *Journal of Cleaner Production*, 278, 123938.
 17. Froehle, Kamryn, Adam R. Phillips, and Homero Murzi. "Lifelong Learning Is an Ethical Responsibility of Professional Engineers: Is School Preparing Young Engineers for Lifelong Learning?" *Journal of Civil Engineering Education* 147.3 (2021): 02521002.
 18. Allan, K., & Phillips, A. R. (2021). Comparative Cradle-to-Grave Life Cycle Assessment of Low and Mid-Rise Mass Timber Buildings with Equivalent Structural Steel Alternatives. *Sustainability*, 13(6), 3401.
 19. Xie, R., Lu, L., Qiao, P., & Zhou, Z. (2021). Nanoindentation-based micromechanical characterisation of ultra-high-performance concrete exposed to freezing–thawing. *Magazine of Concrete Research*, 1-15.
 20. Liu, M., Liu, D., Qiao, P., & Sun, L. (2021). Characterization of microstructural damage evolution of freeze-thawed shotcrete by an integrative micro-CT and nanoindentation statistical approach. *Cement and Concrete Composites*, 117, 103909.
 21. Pathirana, S., & Qiao, P. (2020). Elastic local buckling of periodic sinusoidal corrugated composite panels subjected to in-plane shear. *Thin-Walled Structures*, 157, 107134.
 22. Yu, H., Lu, L., & Qiao, P. (2020). Thermo-mechanical modeling and characterization of three-phase shape memory alloy hybrid composites. *Smart Materials and Structures*, 30(1), 015010.
 23. Wright, J. W., & Pantelides, C. P. (2021). Axial compression capacity of concrete columns reinforced with corrosion-resistant metallic reinforcement. *Journal of Infrastructure Preservation and Resilience*, 2(1), 1-15.
 24. Coppola, N. and Marshall, W. 2021. Sidewalk Static Obstructions and the Impact on Clear Width. [Transportation Research Record \(doi.org/10.1177/0361198121991833\)](https://doi.org/10.1177/0361198121991833)
 25. Alatif, A. and Kim, Y.J. Surface-dependent interfacial characteristics of GFRP bars in concrete,

American Concrete Institute Spring Convention, March 2021

26. Tazarv, M., Shrestha, G., and Saiidi, M.S. (2021). "State-of-the-Art Review and Design of Grouted Duct Connections for Precast Bridge Columns," *Structures*, Vol. 30, pp. 895-909.
27. Tang, Q., Cheng, Y., Hu, X., Chen, C., Song, Y., Qin, R. (2021). Evaluation Methodology of Leader-Follower Autonomous Vehicle System for Work Zone Maintenance. *Transportation Research Record: Journal of the Transportation Research Board*. <https://doi.org/10.1177%2F0361198120985233>
28. Deng, Y., Yan, S., Zhang, P., Hu, X. (2021). Mining Route Set Distribution Range and Affecting Factor Threshold Based on GPS Data. *Transportation Research Record: Journal of the Transportation Research Board*. <https://doi.org/10.1177/0361198121999059>
29. Ma, Q., Yang, H., Ma, Y., Yang, D., Hu, X., Xie, K. (2021). An Analysis of Municipal E-Scooter User Guidelines in the United States. *Transportation Research Part D: Transport and Environment*. Volume 92, 102710. <https://doi.org/10.1016/j.trd.2021.102710>
30. Cheng, Y., Tang, Q., Hu, X., Qi, H., Yang, H. (2020). A Monte Carlo Tree Search-Based Mixed Traffic Flow Control Algorithm for Arterial Intersection. *Transportation Research Record: Journal of the Transportation Research Board*. Volume: 2674, issue: 8, page(s): 167-178. <https://doi.org/10.1177%2F0361198120919746>
31. Riad, B., and Zhang, X. (2021). "A consistent three-dimensional elasto-plastic constitutive model to study the hydro-mechanical behavior of unsaturated soils." *Journal of Transportation Research Record (In Press)* DOI: 10.1177/03611981211002217.
32. Houston, S. and Zhang, X. (2021). "Review of expansive and collapsible soil volume change models within a unified elastoplastic framework." *Soils and Rocks*. Keynote Lecture to the 3rd Pan-American Conferences on Unsaturated Soils (Accepted)
33. Zornberg, J. G. and Zhang, X. (2021). "Moving Down the Road of Progress – Geosynthetics Subdue Failures on Expansive Clays and Frost-Susceptible Soils." *Geo-Strata*, Vol. 16, No. 2, pp. 48-55.
34. Lin, C., Galinmoghadam, J., Han, J., Liu, J., and Zhang, X. (2020). "Quantifying and Incorporating the Benefits of Wicking Geotextile into Pavement Design." *ASCE Journal of Transportation Engineering Part B: Pavements*. (Accepted)
35. Deng, Y., Yan, S., Zhang, P., Hu, X. (2021). Mining Route Set Distribution Range and Affecting Factor Threshold Based on GPS Data. *Transportation Research Board 100th Annual Meeting, Washington DC*. 2021.
36. Q. Tang, X. Hu, A. Nylen, T. Weldon. Usage of Microscopic Traffic Simulation to Quantify Traffic Impact of Autonomous Maintenance Technology. Accepted for presentation at TRB Workshop on Traffic Simulation and CAV Modeling. Nov. 16-18, 2020.
37. J. Liu, J. Liu, and S. Saboundjian, "Evaluation of Cracking Susceptibility of Alaskan Polymer Modified Asphalt Binders Using Chemical and Rheological Indices", *Construction & Building Materials* (in press).
38. J. Liu, J. Liu, and G. Hao, "Chemical Aging Indices and Rheological Parameters for Cracking Susceptibility Evaluation of Alaskan Polymer Modified Asphalt Binders", *ASCE Journal of Materials in Civil Engineering*, 33(3), [https://doi.org/10.1061/\(ASCE\)MT.1943-5533.0003627](https://doi.org/10.1061/(ASCE)MT.1943-5533.0003627), 2021.
39. F. Ma, W. Dong, Z. Fu, R. Wang, Y. Huang, and J. Liu, "Life cycle assessment of greenhouse gas emissions from asphalt pavement maintenance: A case study in China", *Journal of Cleaner Production*, Volume 288, 15 March 2021, 125595, <https://doi.org/10.1016/j.jclepro.2020.125595>.
40. W. Dong, F. Ma, Z. Fu, C. Li, Y. Huang, and J. Liu, "Evaluation of Anti-aging Performance of Biochar Modified Asphalt", *Coatings*, 10(11), 1037, 2020
41. J. Liu, J. Liu, A. Zhu, and S. Saboundjian, "Evaluation of Multiple Stress Creep Recovery Test on Alaskan Asphalt Binders", *ASCE Journal of Materials in Civil Engineering*, 32(10): 04020302, 2020.
42. Wright, J.W., and Pantelides, C.P. (2021). "Axial compression capacity of concrete columns reinforced with corrosion-resistant metallic reinforcement." *J. Infrastruct. Preserv. Resil.* 2, 2 (2021). <https://doi.org/10.1186/s43065-021-00016-3>.
43. Safazadeh, F., Romero, P., Asib, ASM, and VanFrank, K.: "Practicality of Driven Parameters of Semi-Circular Bending (SCB) Test at Intermediate Temperature" Paper PVENG-746R3, *ASCE Journal of Transportation Engineering, Part B: Pavements* (Forthcoming)
44. Asib, ASM, Romero, P.: "A Long-Term Field Study of the Ability to Predict Thermal Cracking of Asphalt Mixtures Tested by the Bending Beam Rheometer" Paper RMPD-20-08-53.R1, *Road Materials and Pavement Design* (Forthcoming)
45. Ghasemi, S. H., & Lee, J. Y. (2021). Reliability-based indicator for post-earthquake traffic flow capacity of a highway bridge. *Structural Safety*, 89, 102039.
46. Ghasemi, S.H. and Lee, J.Y. (2021). "Measuring instantaneous resilience of a highway bridge subjected

to earthquake events.” Transportation Research Record. Accepted.

Technical Reports

1. F.J. Presuel-Moreno, K. Hoque, A. Rosa-Pagan “Corrosion Propagation of Carbon Steel Rebar Embedded in Binary and Ternary Concrete Mixes” Research in Progress during the CORROSION 2021 conference. (The presentation will take place during April 2021, but the presentation has been recorded and uploaded.)
2. Texas A&M Task Report, “Durability of Transverse Sawcut Joints in Mid-Western Jointed Concrete Pavements,” March 12, 2021.

Presentations

1. Shi, X. Six Key Elements of High-Quality Technical Writing. Invited seminar for the WSU CEE Graduate Students (and some non-WSU researchers), Feb. 22, 2021. Online.
2. Shi, X. Durability of Concrete Materials in Cold Regions: Emerging Challenges and Countermeasures. Plenary talk at the 1st Civil Engineering HuXiang Forum (Theme: Greenization and Intelligentization of Bridge and Building Structures), Dec. 20, 2020, Changsha, Hunan. Online.
3. Shi, X. Concrete as a Construction Material: Unique Characteristics and Recent Advances. Invited Guest Lecture for the ACI student chapter, University of the District of Columbia, Nov. 9, 2020, online.
4. Shi, X. Concrete as a Construction Material: Unique Characteristics and Recent Advances. Invited Guest Lecture for the School of Mechanical and Materials Engineering, Washington State University, Course ME110, Oct. 29, 2020, online.
5. Nazari, M.H., Shi, X. Bio-based Renewable Additives for Anti-icing Applications. A poster presentation at the 100th TRB Annual Meeting, Jan. 27, 2021, online.
6. Shi, X., Deng, Y. Developing Enhanced Performance Curves for ITD Asphalt Pavements. University of Idaho – Idaho Transportation Department Research Progress Meeting, online, Oct. 23, 2020.
7. Tazarv and Won. (2021). “Post-Earthquake Serviceability of RC Bridge Bents Using Visual Inspection,” Presentation to Project Panel, Feb. 9.
8. Tazarv, M., Dahal, P., Saiidi, MS. (2020) “Design of Mechanically Spliced Precast Bridge Columns for High-Seismic Regions,” ACI Fall 2020 Convention, Raleigh, NC, Oct. 25.
9. Jenny Liu, Use of Low-Density Cellular Concrete for Air Convection Embankment to Protect Permafrost Foundations in Cold Regions, Aerix Industries™ Signature Series Webinar, February 2021.
10. Feasibility Study on Novel Fire Resistant Coating Materials, 100th TRB Annual Meeting, January 2021 (virtual).
11. Anyou Zhu, Hanli Wu, Jenny Liu. “Feasibility study on novel fire-resistant coating materials”, presented at 1461 - Emerging Concrete Technology section, 100th TRB Annual Meeting, January 2021.
12. Xiaolong Xia, Xiong Zhang, Sara Fayek, and Zhaozheng Yin. “A table method for coded target decoding with application to 3-D reconstruction of soil samples during triaxial testing”, presented at 1176 – Improving Site Characterization and Reliability with Innovative Laboratory and Field Testing section, 100th TRB Annual Meeting, January 2021.
13. Beshoy Riad, and Xiong Zhang. “A consistent three-dimensional elasto-plastic model to study unsaturated soil behavior with considerations of coupled hydro-mechanical hysteresis”, presented at 1137 – Effect of Moisture on Subgrade Soil section, 100th TRB Annual Meeting, January 2021.
14. Sara Fayek, Xiong Zhang, and Xiong Zhang. “A critical assessment of soil disturbances during triaxial testing using a photogrammetry-based method”, presented at 1176 – Improving Site Characterization and Reliability with Innovative Laboratory and Field Testing section, 100th TRB Annual Meeting, January 2021.
15. Yajuan Deng, Sanghuiyu Yan, Peng Zhang, and Xianbiao Hu. “Mining route set distribution range and affecting factor threshold based on GPS data”, presented at 1170 – Mining Data Deeper to Understand Travel Behavior section, 100th TRB Annual Meeting, January 2021.
16. Paper TRB 21-03995: ‘Correlation between Laboratory and Natural Aging Using the Low-Temperature Performance Test with Bending Beam Rheometer’ by ASM Asib and P. Romero. was presented at the 100th meeting of the Transportation Research Board
17. A presentation at the 2021 Utah Asphalt Conference on the topic of Asphalt Mixture Testing was done by Dr. Pedro Romero on March 18, 2021
18. A webinar presentation was made by Professor Pantelides during the monthly TriDurLE webinars on November 17, 2020, titled “Axial Compression Capacity of Concrete Columns reinforced with corrosion-resistant hybrid reinforcement.”

19. Paper TRB 21-03995: 'Correlation between Laboratory and Natural Aging Using the Low-Temperature Performance Test with Bending Beam Rheometer' by ASM Asif and P. Romero was presented at the 100th meeting of the Transportation Research Board
20. A presentation at the 2021 Utah Asphalt Conference on the topic of Asphalt Mixture Testing was done by Dr. Pedro Romero on March 18, 2021
21. Ghasemi, S.H. and Lee, J.Y. (2021). "Measuring instantaneous resilience of a highway bridge subjected to earthquake events." was presented at the 100th meeting of the Transportation Research Board.

3.2 Website(s) or other internet site(s)

SDSU: Research Website: <https://sites.google.com/people.unr.edu/mostafa-tazarv/research/post-event-serviceability>

TriDurLE Website: <https://tridurle.wsu.edu>

3.3 Technologies or techniques

None to report

3.4 Inventions, patent applications, and/or licenses

None to report

3.5 Other output

None to report

4. OUTCOMES

4.1 Increased understanding and awareness of transportation issues

The collaborative project between UC Denver and University of Utah advances the state of the art of transportation structures through understanding the durability of bridge piers. Little is known about the performance of accelerated bridge construction (ABC) columns subjected to corrosion damage. The research is at the forefront of cost-effective construction methods. The other project on the evaluation of sidewalk uses big data and geographic information system (GIS) technologies to understand the life extension of the built-environments.

4.2 Passage of new policies, regulation, rulemaking, or legislation

None to report

4.3 Increases in the body of knowledge

The ABC column projects employs agent-based modeling to elucidate the corrosion mechanisms of bridge structures. This approach has not been used previously in the structural engineering community; accordingly, the research advances the state of the art of infrastructure engineering.

4.4 Improvement of existing techniques, practices, technologies

The sidewalk project is based on the application of geographic information system (GIS), which is built upon existing techniques and expand the implementation boundaries.

4.5 Enlargement of the pool of trained transportation professionals

Participating researchers are trained to learn the state of the art of infrastructure engineering. After the end of the pandemic era, more active involvement is expected.

4.6 Incorporation of new techniques, practices, technologies

As stated above, the bridge project handles new technologies to predict the chloride migration mechanisms in ABC columns. Compared with conventional methods, refined and accurate results are obtained.

5. IMPACTS

The National UTC TriDurLE is conducting a variety of research, education and outreach, workforce development, technology transfer, and diversity activities, but because of delays due to COVID, the impacts of this program may not be fully measured during this reporting period.

5.1 What is the impact on the development of the principal discipline(s) of the program?

Texas A&M reports that the results of its proposed research will be in the form of a management tool to minimize or prevent a serious form of joint deterioration that mainly occurs in regions of the US subject to F/T conditions where deicers are commonly used.

5.2 What is the impact on other disciplines?

Nothing to Report.

5.3 What is the impact on the development of transportation workforce development?

The result of this proposed research conducted by Texas A&M will affect the workforce development to oversee inspections and training of various practice elements of the joint sealant. A decision-making tool will be far reaching and significant, especially for the future use of jointed concrete pavements in the Midwest. Decision-makers need tools and guidance as to the management of the pavement infrastructure to gain decades of service life beyond is presently realized.

5.4 What is the impact on physical, institutional, and information resources at the university or other partner institutions?

Nothing to Report.

5.5 What is the impact on technology transfer?

Texas A&M reports that decision-makers need tools and guidance as to the management of the pavement infrastructure to gain decades of service life beyond what is presently realized. The type of technology transfer involved in its research project would fit well within the mission of the TriDurLE and would provide the means for practitioners and managers to make timely and cost-effective maintenance-related decisions.

5.6 What is the impact on society beyond science and technology?

Some TriDurLE researchers or their studies have been reported in the national media; some examples are provided as follows:

- A paper by Xianming Shi and Gang Xu titled “Characteristics and applications of fly ash as a sustainable construction material: state-of-the-art review” (published in 2018) was awarded the 2020 Most Cited Paper Award by Resources Conservation & Recycling
- Professor Issam Harik, a member of the TriDurLE Advisory Committee, won the prestigious ACI Design Award bestowed by the American Concrete Institute: “Improving the Durability of Impact Damaged Pc Bridge Girders Using CFRP Rod Panel Retrofit”, SP331-06, February 2019, pp. 80-100.
- Dr. Xiong Zhang, professor of civil, architectural and environmental engineering at MST and TriDurLE researcher, received the 2020 Faculty Research Award. The Faculty Research Award recognizes faculty members who have demonstrated excellence in research and scholarship.
- Dr. Xianbiao Hu from the Department of Civil, Architectural, and Environmental Engineering at Missouri S&T received the Outstanding Associated Editor Award from the International Journal of Transportation Science and Technology.
- Dr. Xiong Zhang from the Department of Civil, Architectural, and Environmental Engineering at Missouri S&T was invited to serve as associate editor of ASCE Journal of Cold Regions Engineering

6. CHANGES/PROBLEMS

6.1 Changes in approach and reasons for change

The COVID-19 pandemic and associated lockdowns starting March 2020 has caused delay in research activities due to quarantines and university shutdowns. Temporary loss of access to laboratory facilities and cancellation of conferences and other professional activities has resulted in decreased ability to network and conduct research. Lockdowns have also resulted in decreased ability to recruit students.

The University of Utah researchers reported that the column testing scheduled at North East Forest University in China was not available due to the closure of the laboratory. It is not clear when the laboratory will reopen. The research team is planning on an alternative test at the University of Colorado Denver or on revising the plan by adding more contents to the modeling component. For this reason, from Year 2, the partner will be changed to Yamaguchi University in Japan. Large-scaling testing at the University of Utah will continue.

Texas A&M reported that although joint sealant performance models were planned to be collected through field performance data collection, field data on the condition of joint sealant and deicing agent were very rare, according to investigations in Task 1. Therefore, the plan has been revised to analyze more diverse data collected in the laboratory. However, the collection of field data continues.

Florida Atlantic University reports: Due to COVID-19, the team had limited access to the labs during fall 2021. Starting January 2021, it has been easier to access the labs.

6.2 Actual or anticipated problems or delays and actions or plans to resolve them

Laboratory testing has been delayed due to the shutdown of some universities. Research teams will need to file for no-cost extensions.

6.3 Changes that have a significant impact on expenditures

Nothing to report

6.4 Significant change in use or care of animals, human subjects, and/or biohazards

N/A

6.5 Changes of primary performance site location from that originally proposed

Nothing to Report

6.6 Additional information regarding products and impacts

7. SPECIAL REPORTING REQUIREMENTS

1. **Website:** <https://tridurle.wsu.edu/>
2. **Directory of Advisory Board:** Available on the program website: <https://tridurle.wsu.edu/advisory-board/>
3. **Directory of Key Personnel:** Available on the program website: <https://tridurle.wsu.edu/staff/>
4. **Financial and Annual Recipient Share Reports:** The Federal Financial Report (SF-425) requirements will be met by separate reports.
5. **Research Project Descriptions:** Available on the program website <https://tridurle.wsu.edu/research/>

APPENDIX

TriDurLE Year one approved projects, addressing a broad array of important issues and exhibiting important research collaboration among our consortium. We are currently receiving proposals for Year 2. Please visit tridurle.wsu.edu/research/ for more information on years one and two research projects.

1. Evaluation of Downdrag Loads on Bridge Pile Foundations in Inundated Collapsible Soils. Researcher: Dr. Mohamad Ashour, Alabama A&M University
2. Fatigue Life Analysis of Reinforced Concrete Beams Strengthened with Composites. Researcher: Dr. Christian Carloni, Case Western Reserve University
3. Development of Environmental Responsive Asphalt Technology for Asphalt Pavement Life Extension. Researcher: Dr. Xiong (Bill) Yu, Case Western Reserve University
4. Develop an Innovative Self-Healing Concrete Technology for Bridge Deck Life Extension. Researcher: Dr. Xiong (Bill) Yu, Case Western Reserve University
5. Corrosion Propagation Monitoring Using Galvanostatic Pulse on Reinforced Concrete Legacy Samples. Researcher: Dr. Francisco Presuel-Moreno, Florida Atlantic University
6. Modeling and Measurement of Rebar Corrosion on Crack Formation Using High Frequency Ultrasonics in Three Dimensions and with No Contact with the Sample. Researcher: Dr. Pierre-Phillipe Beaujean, Florida Atlantic University
7. Use of Recycled Plastics in Asphalt Pavements. Researcher: Dr. Jenny Liu, Missouri University of Science & Technology
8. Development of Holistic Methodologies for Improving Asphalt Mix Durability. Researchers: Dr. Jenny Liu, Missouri University of Science & Technology, Fujie Zhou, Texas A&M, and Pedro Romero, University of Utah
9. Exploring the Feasibility of Innovative Integration of Place Change Materials for Thermo-Adaptive Asphalt Pavements. Researcher: Dr. Jenny Liu, Missouri University of Science & Technology
10. Analyzing the Impact of Autonomous Maintenance Technology to Transportation Infrastructure Capacity for Condition Monitoring and Performance Management. Researcher: Dr. Xianbiao (XB) Hu, Missouri University of Science & Technology
11. Automated Detection of Characterization of Cracks Using Structure-From-Motion Based Photogrammetry: A Feasibility Study. Researcher: Dr. Xiong Zhang, Missouri University of Science & Technology
12. Extended Monitoring of Performance of Wicking Geotextile to Mitigate Pumping in Pavement Shoulder. Researcher: Dr. Xiong Zhang, Missouri University of Science & Technology
13. Numerical Simulation of Pavement Installed with Wicking Geotextile in Responses to Climatic Conditions. Researcher: Dr. Xiong Zhang, Missouri University of Science & Technology
14. Post-Earthquake Serviceability of RC Bridge Bents Using Visual Inspection. Researcher: Dr. Mostafa Tazarv, South Dakota State University
15. Durability of Transverse Sawcut Joints in Mid-Western Jointed Concrete Pavements. Researchers: Dr. Dan Zollinger, Texas A&M University, Dr. Jenny Liu, Missouri University of Science & Technology
16. Highway Pavement Condition Deterioration Modeling Considering Maintenance History. Researchers: Dr. Waheed Uddin, PI, and Dr. Hakan Yasarer, Co-PI, The University of Mississippi
17. Evaluating Sidewalk Infrastructure Durability and Life Extension. Researchers: Dr. Wesley Marshall, PI, and Dr. Arunprakash Karkunanithi, Co-PI, University of Colorado, Denver
18. Performance of ABC Columns and Cost-Effective Retrofit Strategies Subjected to Synergistic Distress Resulting from Corrosion and Seismic Loading. Researchers: Dr. Chris Pantelides, PI, University of Utah, and Dr. Yail Jimmy Kim, PI, University of Colorado Denver
19. Design of Long-Lasting Discrete Sacrificial Anode for Corrosion Mitigation of Reinforcement in Chloride Contaminated Concrete. Researcher: Dr. Xianming Shi, Washington State University
20. Impacts of Magnesium Chloride Deicer on the Durability of Nanosilica-Modified HVA Concrete. Researcher: Dr. Xianming Shi, Washington State University
21. Development of a Multi-Scale Self-Healing High-Volume Fly Ash UHPC. Researcher: Dr. Xianming Shi, Washington State University
22. Developing Enhanced Performance Curves of ITD Asphalt Pavements by Mining the Historical Data. Researcher: Dr. Xianming Shi, Washington State University
23. An Innovative Approach to Enhance Self-Healing in Cementitiously Stabilized Soils and Mitigate Shrinkage Cracking. Researcher: Dr. Muhunthan Balasingam, Washington State University
24. Multi-Level Resilience-Based Transportation Asset Management (TAM) Framework using Bayesian

Network. Researchers: Dr. Ji Yun Lee PI, Washington State University, Dr. Yue Li, PI, Case Western Reserve University, and Dr. Xiong Yu, Co-PI, Case Western Reserve University

25. Fiber Reinforced Polymer (FRP) Seismic Retrofit of Reinforced Concrete Bridge Columns Vulnerable to Long-Duration Subduction Zone Earthquakes. Researchers: Dr. Christopher Motter, PI, and Dr. Adam Phillips, Co-PI, Washington State University
26. Test Methods and Bond Performance Characterization of Shotcrete-Concrete Interface. Researcher: Dr. Pizhong Qiao, Washington State University.