



**TriDurLE**

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

## **USDOT National University Transportation Center Progress Performance Report**

|                                          |                                                                                                                                                                          |
|------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Submitted to</b>                      | U.S. Department of Transportation<br>Office of the Assistant Secretary for Research and<br>Technology (OST-R)                                                            |
| <b>Grant Number:</b>                     | 69A3551947137                                                                                                                                                            |
| <b>Project Title:</b>                    | National Center for Transportation Infrastructure Durability<br>& Life-Extension (TriDurLE)                                                                              |
| <b>Center Director:</b>                  | Xianming Shi, Ph.D., P.E. Associate Professor                                                                                                                            |
| <b>University</b>                        | Department of Civil and Environmental Engineering Washington State<br>Pullman, WA 99163<br><a href="mailto:xianming.shi@wsu.edu">xianming.shi@wsu.edu</a>   509-335-7088 |
| <b>Submission Date:</b>                  | April 30, 2022                                                                                                                                                           |
| <b>DUNS:</b>                             | 04-148-5301                                                                                                                                                              |
| <b>EIN:</b>                              | 91-6001108                                                                                                                                                               |
| <b>Recipient Organization:</b>           | Washington State University                                                                                                                                              |
| <b>Project/Grant Period:</b>             | July 1, 2019 - September 30, 2023                                                                                                                                        |
| <b>Reporting Period Start Date:</b>      | October 1, 2021                                                                                                                                                          |
| <b>Reporting Period End Date:</b>        | March 31, 2022                                                                                                                                                           |
| <b>Report Term or Frequency:</b>         | Semi-annual                                                                                                                                                              |
| <b>Signature of Submitting Official:</b> |                                                                                       |

## TABLE OF CONTENTS

|                                                                                                            |           |
|------------------------------------------------------------------------------------------------------------|-----------|
| <b>1. ACCOMPLISHMENTS</b>                                                                                  | <b>4</b>  |
| <b>1.1 What are the major goals and objectives of the program?</b>                                         | <b>4</b>  |
| Center Strategic Goals .....                                                                               | 4         |
| <b>1.2 What was accomplished under these goals?</b>                                                        | <b>4</b>  |
| Research .....                                                                                             | 4         |
| Leadership.....                                                                                            | 4         |
| Education and Workforce Development .....                                                                  | 5         |
| Technology Transfer .....                                                                                  | 6         |
| Collaboration .....                                                                                        | 6         |
| Diversity .....                                                                                            | 6         |
| <b>1.3 What opportunities for training and professional development has the program offered?</b>           | <b>7</b>  |
| <b>1.4 How have the results been disseminated?</b>                                                         | <b>7</b>  |
| <b>1.5 What do you plan to do during the next reporting period to accomplish the goals and objectives?</b> | <b>7</b>  |
| <b>2. PARTICIPANTS AND COLLABORATING ORGANIZATIONS</b>                                                     | <b>7</b>  |
| <b>2.1 Who has worked on the program?</b>                                                                  | <b>7</b>  |
| <b>2.2 What organizations have been involved as partners?</b>                                              | <b>8</b>  |
| <b>2.3 Have other collaborators or contacts been involved?</b>                                             | <b>9</b>  |
| <b>3. OUTPUTS</b>                                                                                          | <b>10</b> |
| <div><b>3. OUTPUTS</b></div>                                                                               |           |
|                                                                                                            | <b>10</b> |
| <b>3.1 Publications, conference papers, and presentations</b>                                              | <b>10</b> |
| Publications.....                                                                                          | 10        |
| Technical Reports.....                                                                                     | 12        |
| Presentations.....                                                                                         | 13        |
| <b>3.2 Website(s) or other internet site(s)</b>                                                            | <b>15</b> |
| <b>3.3 Technologies or techniques</b>                                                                      | <b>16</b> |
| <b>3.4 Inventions, patent applications, and/or licenses</b>                                                | <b>16</b> |
| <b>3.5 Other output</b>                                                                                    | <b>16</b> |
| <b>4. OUTCOMES</b>                                                                                         | <b>16</b> |
| <b>4.1 Increased understanding and awareness of transportation issues</b>                                  | <b>16</b> |
| <b>4.2 Passage of new policies, regulation, rulemaking, or legislation</b>                                 | <b>16</b> |

|                                                                                                                                     |           |
|-------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 4.3 Increases in the body of knowledge _____                                                                                        | 16        |
| 4.4 Improvement of existing techniques, practices, technologies _____                                                               | 17        |
| 4.5 Enlargement of the pool of trained transportation professionals _____                                                           | 17        |
| 4.6 Incorporation of new techniques, practices, technologies _____                                                                  | 17        |
| <b>5. IMPACTS _____</b>                                                                                                             | <b>17</b> |
| 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? _____                                                        | 17        |
| 5.4 What is the impact on physical, institutional, and information resources at the university or other partner institutions? _____ | 18        |
| 5.5 What is the impact on technology transfer? _____                                                                                | 18        |
| 5.6 What is the impact on society beyond science and technology? _____                                                              | 18        |
| <b>6. CHANGES/PROBLEMS _____</b>                                                                                                    | <b>18</b> |
| 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        |
| <b>7. SPECIAL REPORTING REQUIREMENTS _____</b>                                                                                      | <b>19</b> |
| <b>APPENDIX A _____</b>                                                                                                             | <b>20</b> |

# 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.

## 1.2 What was accomplished under these goals?

### Research

TriDurLE is funding a total of 52 projects for both years one and two. No-cost time extensions were awarded for some year-one projects because of COVID-19 delays that limited access to laboratory facilities, supply chain issues, and potential difficulties in student recruitment. The 26 year-one research projects have made reasonable progress in spite of these challenges, and five have been completed along with their final reports and raw data file submissions. The remaining year-one projects will be completed between June – September 2022. Appendix A contains the list of year-two projects that have been funded with respect to each member university.

Each consortium university reported on the progress of its research projects, but length constraints prevent from including these details.

### 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. In addition to the presentation and publications reports in subsequent sections, following is a list of leadership activities conducted by consortium members during this reporting period:

Dr. Chris Pantelides of University of Utah served as Chair of the Academic Committee for the inaugural 2021 TriDurLE Symposium.

Dr. Yail Jimmy Kim, of UC Denver serves as President of the Bridge Engineering Institute (BEI), An International Technical Society, and a voting member of several national technical committees. He moderated two special sessions during the fall convention of the American Concrete Institute (Durability, Service Life, and Long-Term Integrity of Concrete Materials, Bridges, and Structures (Parts 1 and 2) on Oct. 21, 2021 with colleagues (Dr. C. Pantelides and Dr. X. Shi).

MST: Xiong Zhang, was Keynote Speaker, Transportation Research Congress 2021, November 5-7, 2021 Hangzhou, China (Virtual) and 5th International Conference on Transportation Infrastructure and Materials, October 21-22, 2021(Virtual). XB Hu was appointed the Committee Research Coordinator, TRB AKR10 Maintenance and Operation Committee, January 2022. Jenny Liu, Xiong Zhang, and XB Hu were session chairs, and members of organizing committee, Transportation Research Congress, November 5-7, 2021 (virtual). Jenny Liu was chair of Scientific Committee, 5th International Conference on Transportation Infrastructure and Materials, Oct 21-22, 2021 (virtual).

Jenny Liu was elected to be the vice-president of International Association of Chinese Infrastructure Professionals (IACIP), January 2022.

Christian Carloni of CWRU discussed the results of research at ACI 440K/ASTM D.30.10 Committee to improve current standards

Dr. Xiong (Bill) Yu of CWRU is actively involved in working groups by the ASCE on risk-based geotechnical design guide to promote the adaptation to climate change by institute resilience to infrastructure and materials

Dr. Xianming Shi of WSU, Interim Chair of Civil and Environmental Engineering Department:  
DIRECTOR, National Center for Transportation Infrastructure Durability & Life-Extension (TriDurLE), July 2019 - Present  
Founding Editor-in-Chief, Journal of Infrastructure Preservation and Resilience, by Springer-Nature, Jan. 2019 – Present  
Organizing committee, 5<sup>th</sup> International Conference on Transportation Infrastructure and Materials, Oct. 21-22, 2021, Changsha, China.

## Education and Workforce Development

### Student awards

- Sayal Shrestha, a PhD student at the University of Utah received the 2022 American Concrete Intermountain Chapter Scholarship.
- Abdullal Mamun, a Ph.D. Student at the University of Utah received the Utah Asphalt Paving Association Award during their 2022 Utah Asphalt Conference.
- Hanli Wu of MST, Outstanding Graduate Student Award, IACIP, 3rd place, 202, and IACIP Poster Award, 1st place, 2022 Anyou Zhu of MST, IACIP Poster Award, 2<sup>nd</sup> place, 2022; Beshoy Riad of MST, Best Presentation Award, 1st Annual Symposium of National Center for Transportation on Infrastructure Durability & Life-extension, 2021.

At University of Utah a new PhD student began working on the project in January 2021 and an undergraduate student received a scholarship from TriDurLE as a Research Experience intern. Two new graduates will be also hired in 2022 and the research will be conducted both in the United States and at the UU Asia Campus in Incheon, Republic of Korea.

At Florida Atlantic University, a master's student has successfully completed his thesis proposal and is scheduled to receive his degree in August 2022. (Beaujean). Another master's student successfully completed his MS thesis.

Dr. Kim of UC Denver has been advising two post-docs, five PhD and seven MS students. Graduate students learn how to plan research tasks, how to develop models, how to simulate given problems, and how to interpret calculated data. Based on these training approaches, they can become competitive structural engineers. Dr. Wesley Marshall of UCD noted that projects there are having an impact on students by providing an opportunity for research and skill development

Washington State University student Ayumi Manawadu represented WSU as the Western Regional winner at the National Three-Minute Thesis (3MT) Showcase, WTS Paula Hammond Leadership Legacy Scholarship - National Winner, WE Local-Buffalo NY Student Research Competition Winner, Outstanding poster award – 1<sup>st</sup> Annual Symposium of National Centre for Transportation Infrastructure Durability and Life Extension, Society of Women Engineers Outstanding Collegiate Member, WSU Graduate Student Woman of Distinction . Drs. Phillip and Motter report that their project has aided in workforce development through training of several M.S. thesis students, included one who has graduated and currently works in Seattle, WA, and three who are expected to graduate between August and December of 2022. In addition: Mehdi H. Nazari was the winner of Outstanding Research Assistant Award, selected by the Department of Civil & Environmental Engineering, Washington State University, 2022; Zhipeng Li was the winner of Dissertation Award, Dept. of Civil & Environmental Engineering, WSU, 2022; Yan Zhang was the winner of Milton Pikarsky Memorial Award for Outstanding Doctoral Dissertation, 2021.

CWRU is incorporating research progress into course modules to train the next generation.

## Technology Transfer

Christian Carloni of CWRU Developed a new test with the industry partner (Sireg, Italy) to invest the relationship between the opening of flexural cracks and the bond of the bars in reinforced concrete structures. Drs. Phillips and Motter's TriDurLE project has been used to educate engineers at WSDOT on the performance of FRP retrofitted columns compared to their current solution of steel jacket retrofitted columns. The PI's have given several presentations to the WSDOT bridge design office on the results of the FRP column tests. The project results of the FRP column tests will also be communicated to the industry sponsor, Simpson Strong-Tie, for their use in developing new application for their FRP product lines.

## Collaboration

Section 2 of this report details the extensive collaboration of TriDurLE researchers with industries and universities. In addition, several of the TriDurLE research projects are collaborative within the consortium, such as Washington State University and Case Western Research University, and Texas A&M University and Missouri University of Science and Technology.

## Diversity

TriDurLE awarded several diversity initiatives for students, staff, and faculty, including travel grants to meetings that promote diversity, graduate research fellowships for underserved students, and high school/undergraduate scholarships for underserved students to work under the tutelage of TriDurLE researchers. Three students were awarded a Graduate Research Fellowship: Sara Fayek of Missouri S&T; Rodrigo Teixeira Schlosser of CWRU, and Vishnupriya Jonnalagadda of WSU. Four undergraduate students received scholarships during this reporting period and are working with TriDurLE faculty at WSU, UU, UM, MST. Five travel grants were awarded to students to attend conferences. In addition:

- The Alabama A&M University is HBCU (Historically Black College and University)
- University of Utah: Diversity plays a key role in the work. In an effort to attract a more diverse pool of students, Mr. Carlos Manuel Hermoza, of Hispanic descent, has joined the research team as a Ph.D. student at the University of Utah. Two female international M.S. students have been hired, one from China and one from Brazil. The PI, Dr. Pedro Romero, is working with the Equity, Diversity, and Inclusion Office of the University of Utah to pursue the Seal of Excelencia during the 2022-2023 academic year. This is part of the Excelencia in Educacion initiative to elevate Latin success in higher education.
- Washington State University funded several female international engineering graduate students in their doctoral studies. Ayumi Manawadu – Diversity and Inclusion Team Lead of GradSWE at the National Level [GradSWE – Graduate Student Community of the Society of Women Engineers]. Vishnupriya Jonnalagadda, a PhD student who has been mainly involved in a WSU research project, was selected to receive the Waheed Uddin Diversity Graduate Research Fellowship.
- Florida Atlantic University is a HSI (Hispanic serving institution), The MS student that graduated is of Hispanic descent (Rosa-Pagan). Dr. Presuel teaches a course titled “Marine Materials and Corrosion” spring 2022 with 32 students taking the class and about 25% of Hispanic background. In this class research related to TriDurLE project has been introduced.
- University of Colorado Denver: Dr. Kim's advisees are from diverse pools in terms of gender, race, and educational background. Currently, there are two female students and several multicultural students. These

students help each other and learn from one another.

- CWRU has recruited two African American and one Hispanic student

### **1.3 What opportunities for training and professional development has the program offered?**

The first annual TriDurLE symposium took place virtually December 6 and 7, featuring four keynote speakers, 45 presentations, and 21 student poster presentations from scholars and professionals worldwide who are conducting research on transportation infrastructure. There were more than 125 attendees during the two-day event. All presentations are recorded and posted on our YouTube channel and website.

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 presented 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. <https://tridurle.wsu.edu/invites-speaker-webinar-series/>

### **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, thesis presentations and presentations at professional conferences and workshops. Many TriDurLE researchers also presented during the TriDurLE annual symposium and through monthly webinars.

### **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 2022 Annual Symposium of this National UTC, likely to be held in late fall 2022.
- 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. 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, LinkedIn 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.
- Consortium universities report that they will complete their research and final reports for year one and make progress on year two research projects as specified in their project reports.

## **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                   | Hakan Yasarer              | Site Director                                  |
| University of Utah                          | Chris Pantelides           | Site Director                                  |
| Washington State University                 | Xianming Shi and Jialuo He | Center Director and Assistant 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/<br>Missouri     |   | X | X | X | X |
| Missouri DOT                         | Government/<br>Missouri     | X |   |   | X | X |
| Missouri, City of Rolla              | State/Missouri              |   |   |   |   | X |
| MYKatikrete                          | Industry/India              |   |   |   |   |   |
| Northeast Forestry University        | Government/<br>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/<br>South Dakota | X | X | X |   |   |
| Tencate North America                | Industry                    | X |   |   | X |   |
| Texas A&M University                 | Government/<br>Texas        |   | X | X | X |   |
| The Polytechnic University of Milan  | Government/ Italy           |   | X |   | X |   |
| University of Maryland, College Park | Government/<br>Maryland     |   |   |   | X |   |
| University of Mississippi            | Government/<br>Mississippi  |   | X | X |   |   |
| University of Utah                   | Government/<br>Utah         |   | X | X | X | X |
| Washington State University          | Government/<br>Washington   | X | X | X | X | X |
| Washington State DOT                 | Government/<br>Washington   | X | X |   |   |   |
| Idaho Transportation Department      | Government/<br>Idaho        | X |   |   |   |   |
| Simpson Strong-Tie, Co.              | Industry/<br>California     |   | X |   |   |   |
| Precast/Prestressed Concrete Inst.   | Industry/Illinois           | X |   |   |   |   |
| Gage Brothers                        | Industry/ SD                |   | X | X |   |   |
| Headed Reinforcement, Corp           | Industry/CA                 |   | 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
- Journal of Infrastructure Preservation & Resilience (JIPR, by Springer Nature)
- Bridge Engineering Institute (BEI)
- Alabama Department of Transportation (ALDOT)
- Dr. Yongcheng Ji, Northeast Forestry University
- Seal/No Seal Group
- Crafc0, Inc.
- Dow Chemical Company
- Dr. Nick Ferencak, Assistant Professor of Civil Engineering, University of New Mexico
- Micah Silberman, project executive, The Conco Companies, Kent WA
- Jesse Espy: Pre-mix Inc, Pullman WA
- Dr. Tommaso D'Antino, Politecnico di Milano, Italy
- Dr. Francesco Focacci, E-Campus University, Italy
- Dr. Danny Xiao, University of Wisconsin-Platteville
- Dr. Jing Zhong, Harbin Institute of Technology
- Dr. Hui Peng, Changsha University of Science and Technology

## 3. OUTPUTS

### 3.1 Publications, conference papers, and presentations

#### Publications

- [1] X Zhang, J Hu, X Fan, X Yu (2022). Naturally grown mycelium-composite as sustainable building insulation materials, *Journal of Cleaner Production* 342, 130784.
- [2] Ameli, Z., D'Antino, T., Carloni, C. (2022). A New Predictive Model for FRCM-Confined Columns: a Reflection on the Composite Behavior at Peak Stress. *Construction and Building Materials*. In press.
- [3] Focacci, F., D'Antino, T., Carloni, C. (2022). Tensile Testing of FRCM Coupons for Material Characterization: Discussion on Critical Aspects. *Construction and Building Materials*, in Press.
- [4] Ashour, M., and Abbas, A. (2021) "Mobilized Response of Piles Subjected to Downdrag." *International Journal of Geomechanics*, © ASCE, ISSN 1532-3641. DOI: 10.1061/(ASCE)GM.1943-5622.0002087
- [5] Wright, J.W, and Pantelides, C.P. "Axial compression capacity of concrete columns reinforced with corrosion-resistant hybrid reinforcement." *Construction and Building Materials*, 302, 124209, (2021). <https://doi.org/10.1016/j.conbuildmat.2021.124209>
- [6] Wright, J.W, and Pantelides, C.P. "Axial compression capacity of concrete columns reinforced with corrosion-resistant metallic reinforcement. *Journal of Infrastructure Preservation and Resilience* 2 (1), 1-15, 2021. <https://doi.org/10.1186/s43065-021-00016-3>
- [7] Asib, ASM., Rahman, R., Romero, P., Hoepfner, M., and Mamun, A.: "Physicochemical Characterization of Shot and Long-Term Aged Asphalt Mixtures for Low Temperature Performance." *Journal of Construction and Building Materials*, Volume 319, 126038 (Feb 2022) <https://doi.org/10.1016/j.conbuildmat.2021.126038>
- [8] Presuel-Moreno F., Rosa-Pagan A, Hoque K., "Corrosion propagation monitoring using galvanostatic pulse on reinforced concrete legacy samples", TriDurLE Year 1 Final Report, Project ID: 2020-FAU-02, January 2022
- [9] Wang, J., Liu, C., and Kim, Y.J. 2021. Artificial intelligence for real-time crack detection of ultra-high-performance concrete, *ACI Special Publication on The Concrete Industry in the Era of Artificial Intelligence (ACI-SP-350)*, American Concrete Institute (ACI), 153-166
- [10] Kim, Y.J., Michnimer, D., and Park, H.-G. 2021. Sparse grid modeling of CFRP-strengthened pilotis under biaxial load, *ACI Structural Journal*, American Concrete Institute (ACI) 118(6), 19-32
- [11] Wang, J. and Kim, Y.J. 2022. Durability of a bridge column under marine environments, *ACI Special Publication*

- on Durability, service life, and long-term integrity of concrete materials, bridges, and structures (ACI-SP-351), American Concrete Institute (ACI), 70-82
- [13] Kim, Y.J. 2022. Long-term behavior of GFRP-reinforced columns under multiaxial loading, *ACI Structural Journal*, American Concrete Institute (ACI) 119(2), 31-44
  - [14] Kim, Y.J. and Alqurashi, A.\* 2022. Torsion of CFRP-strengthened inverted tee-beams under combined loading, *ACI Structural Journal*, American Concrete Institute (ACI) 119(1), 27-40
  - [15] Kim, Y.J., Jung, W.-T., Kang, J.-Y., and Park, J.S. 2022. Testing methods and design specifications for CFRP-prestressed concrete members, *Case Studies in Construction Materials*, Elsevier, 16, e00842
  - [16] Coppola, Nick and Wesley Marshall. Prioritizing Sidewalk Infrastructure: Where Do We Start? *Transportation Research Board*; Washington, D.C.; January 2022.
  - [17] Zhu, H. Wu, and J. Liu. (2022). "Feasibility Study on Novel Fire Resistant Coating Materials", *ASCE Journal of Materials in Civil Engineering*, DOI: 10.1061/(ASCE)MT.1943-5533.0004233 (in press).
  - [18] D. Murph, J. Liu, and J. Liu. (2022). "Mix Designs of Abrasion Resistant and Durable Concrete Made with SCMs for Cold Climates", *ASCE Journal of Transportation Engineering Part B: Pavements* (in press).
  - [19] Fayek, S., Xia, X. and Zhang, X. "Consideration of One Camera Photogrammetry-Based Method to Reevaluate Some Aspects of Conventional Triaxial Methods." *GeoCongress 2022*, Charlotte, NC, March 20-23, 2022 (pp. 141-151).
  - [20] H. Wu, D. Wang, X. Zhang, and J. Liu. (2022). "Impacts of Lightweight Aggregates Interlayers for Air Convection Embankment on Pavement Thermal Profile and Pavement Performance in Alaskan Permafrost Regions", *Transportation Research Record* (accepted).
  - [21] J. Galinmoghadam, J. Liu, X. Zhang, C. Lin, and Y. Guo. (2022). "Mitigating Pumping in Concrete Pavement Shoulder Using Wicking Geotextile: An Experimental Study", *Transportation Research Record* (accepted).
  - [22] J. Liu and J. Liu. (2021). "Prediction Models for Low-Temperature Creep Compliance of Asphalt Mixtures Containing Reclaimed Asphalt Pavement (RAP)", *Construction & Building Materials*, 306, 124915, 2021.
  - [23] J. Liu, J. Liu, and S. Saboundjian. (2022). "Performance Evaluation of Flexible Pavements with Asphalt-treated Base Courses", *Advances in Transportation Geotechnics IV*, 157-167.
  - [24] J. Liu, Y. Wang, and J. Liu. (2022). "Implementation of Linear Amplitude Sweep Test to Evaluate Fatigue Resistance of Highly Polymerized Asphalt Binders", *ASCE Journal of Materials in Civil Engineering*, 34(5):04022070.
  - [25] Liew, M., Xiao, M., Farquharson, L., Nicolsky, D., Jensen, A., Romanovsky, V., Alessa, L., McComb, C., and Zhang, X. (2022). "Understanding Effects of Permafrost Degradation and Coastal Erosion on Civil Infrastructure in Arctic Coastal Towns: A Survey and Knowledge Co-Production." *Journal of Marine Science and Engineering* (In press).
  - [26] Liew, M., Ji, X., Xiao, M., Farquharson, L., Nicolsky, D., Romanovsky, V., Bray, M., Zhang, X., and McComb, C. (2022). "Synthesis of physical processes of permafrost degradation and geophysical and geomechanical properties of permafrost-affected soils." *Cold Regions Science and Technology*, February 2022, 103522 <https://doi.org/10.1016/j.coldregions.2022.103522>.
  - [27] Lin, C., Zhang, X., Galinmoghadam, J., and Guo, Y. (2021). "Working Mechanism of a New Wicking Geotextile in Roadway Applications: A Numerical Study." *Geotextiles and Geomembranes*. <https://doi.org/10.1016/j.geotexmem.2021.11.009> (Available online 4 December 2021)
  - [28] Pei, W., Zhang, M., Lai, Y., Zhang, X., and Luo, T. (2022). "A self-adaption horizontal thermosyphon technology in uneven thermal control of roadway embankments in sub-arctic permafrost regions." *Transportation Geotechnics*, Volume 33, March 2022, <https://doi.org/10.1016/j.trgeo.2021.100714>
  - [29] Riad, B., and Zhang, X. (2021). "A consistent three-dimensional elasto-plastic constative model to study the hydro-mechanical behavior of unsaturated soils." *Journal of Transportation Research Record*, Volume 2675, Issue 9, pp346-369. DOI: 10.1177/03611981211002217.
  - [30] Riad, B., and Zhang, X. (2022). "Fully Characterizing the Elasto-Plastic Hydro-Mechanical Cyclic Behavior of Unsaturated Soils Using Constant Water Content Oedometer and Direct Shear Tests." *Journal of Transportation Research Record*. (Accepted).
  - [31] Xia, X., Fayek, S., and Zhang, X. (2022). "Use of Low-Cost Security Cameras to Measure the Volume-Changes of Unsaturated Soils during Triaxial Testing." *GeoCongress 2022*, Charlotte, NC, March 20-23, 2022.
  - [32] Y. Song, D. Wang, X. Hu, and J. Liu. (2022). "An Efficient and Explainable Ensemble Learning Model for Asphalt Pavement Condition Prediction Based on LTPP Dataset", *IEEE Intelligent Transportation Systems Transactions* (accepted).

- [33] Zaman, W., Han, J., and Zhang, X. (2022). "Technical Review of Development and Applications from Wicking Fabric to Wicking Geotextile." GeoCongress 2022, Charlotte, NC, March 20-23, 2022.
- [34] Tazarv, M., Won, K., Jang, Y., Hart, K., and Greenaway, E. (2022). "Post-Earthquake Serviceability Assessment of Standard RC Bridge Columns Using Computer Vision and Seismic Analyses," Engineering Structures, Federal Support Acknowledged, Under Review.
- [35] Tazarv, M., Won, K., Jang, Y., Hart, K., Greenaway, E., and Harshvardhan, A. (2021). "Post-Earthquake Serviceability Assessment of RC Bridge Columns Using Computer Vision," National Center for Transportation Infrastructure Durability and Life Extension (TriDurLE) Report No: 2020-SDSU-01, Washington State University, Pullman, WA, 338 pp., Federal Support Acknowledged, <https://tridurle.wsu.edu/reports/>
- [36] Deng, Y., Shi, X. Development of Predictive Models of Asphalt Pavement Distresses in Idaho through Gene Expression Programming. *Neural Computing & Applications*, 2022, in press.
- [37] Deng, Y., Shi, X. An Accurate, Reproducible and Robust Model to Predict the Rutting of Asphalt Pavement: Neural Networks Coupled with Particle Swarm Optimization. *IEEE Transactions on Intelligent Transportation Systems*, 2022, DOI: [10.1109/TITS.2022.3149268](https://doi.org/10.1109/TITS.2022.3149268).
- [38] Li, Z., Zhang, Z., Fei, M., Shi, X. Upcycling Waster Mask PP Microfibers in Portland Cement Paste: Surface Treatment by Graphene Oxide. *Materials Letters*, 2022, 318, DOI: [10.1016/j.matlet.2022.132238](https://doi.org/10.1016/j.matlet.2022.132238).
- [39] Wang, X., Feng, D., Shi, X., Zhong, J. Comparative Study of Mechanical Strengths of Cement Pastes Incorporating Carbon Nanomaterials with Distinct Surface Chemistry and Morphology. *Materials Letters*, 2022, DOI: [10.1016/j.matlet.2022.132198](https://doi.org/10.1016/j.matlet.2022.132198).
- [40] Mao, Q., Li, Y., Liu, K., Peng, H., Shi, X. Mechanism, Characterization and Factors of Reaction between Basalt and Alkali: Exploratory Investigation for Potential Application in Geopolymer Concrete. *Cement and Concrete Composites*, 2022, DOI: [10.1016/j.cemconcomp.2022.104526](https://doi.org/10.1016/j.cemconcomp.2022.104526).
- [41] Peng, H., Yang, Y., Ge, Y., Li, Y., Shi, X. Metakaolin-Based Geopolymer Features Different Pore Structure Characteristics from Ordinary Portland Cement Paste: A Mechanistic Study. *ASCE Journal of Materials in Civil Engineering*, 2022, in press.
- [42] Lu, D., Shi, X., Zhong, J. Interfacial Nano-Engineering by Graphene Oxide to Enable Better Utilization of Silica Fume in Cementitious Composite. *Journal of Cleaner Production*, 2022, DOI: [10.1016/j.jclepro.2022.131381](https://doi.org/10.1016/j.jclepro.2022.131381).
- [43] Li, Z., Shi, X. Effects of Nanomaterials on Engineering Performance of a Potassium Methyl Silicate-Based Sealer for Cementitious Composite. *ASCE Journal of Materials in Civil Engineering*, 2022, 34(4), DOI: [10.1061/\(ASCE\)MT.1943-5533.0004148](https://doi.org/10.1061/(ASCE)MT.1943-5533.0004148).
- [44] Zhang, Y., Deng, Y., Shi, X. Model Development and Prediction of Anti-Icing Longevity of Asphalt Pavement with Salt-Storage Additive. *Journal of Infrastructure Preservation and Resilience*, 2022, 3(1), DOI: [10.1186/s43065-021-00047-w](https://doi.org/10.1186/s43065-021-00047-w).
- [45] Lu, D., Shi, X., Zhong, J. Understanding the Role of Unzipped Carbon Nanotubes in Cement Pastes. *Cement and Concrete Composites*, 2022, DOI: [10.1016/j.cemconcomp.2021.104366](https://doi.org/10.1016/j.cemconcomp.2021.104366).
- [46] Nazari, M.H., Zhang, Y., Mahmoodi, A., Xu G., Yu J., Wu J., and Shi, X. Nanocomposite Organic Coatings for Corrosion Protection of Metals: A Review of Recent Advances. *Progress in Organic Coatings*, 2022, 162, DOI: [10.1016/j.porgcoat.2021.106573](https://doi.org/10.1016/j.porgcoat.2021.106573).
- [47] Wang, X., Feng, D., Zhong, J., Shi X. Reinforcement of Cement Paste by Reduced Graphene Oxide: Effect of Dispersion State. *Materials and Structures*, 2022, 55(25), DOI: [10.1617/s11527-021-01826-3](https://doi.org/10.1617/s11527-021-01826-3).
- [48] He, J., Shi, X. Laboratory Assessment of a Self-healing System for Early-Age Durability Benefits to Cementitious Composites. *Journal of Building Engineering*, 2021, 44, DOI: [10.1016/j.job.2021.102602](https://doi.org/10.1016/j.job.2021.102602).
- [49] Li, Z., Xu, G., Shi, X. Reactivity of Coal Fly Ash Used in Cementitious Binder Systems: A State-of-the-Art Overview. *Fuel*, 2021, 301, DOI: [10.1016/j.fuel.2021.121031](https://doi.org/10.1016/j.fuel.2021.121031).
- [50] Zhang, Y., Liu, Z., Shi, X. Development and Use of Salt-Storage Additives in Asphalt Pavement for Anti-icing: Literature Review. *ASCE Journal of Transportation Engineering, Part B: Pavements*, 2021, DOI: [10.1061/JPEODX.0000311](https://doi.org/10.1061/JPEODX.0000311).

## Technical Reports

- [1] Coppola, Nick. and Wesley E. Marshall. Evaluating Sidewalk Infrastructure & Prioritizing Investment. The National Center for Transportation Infrastructure Durability and Life-Extension (TriDurLE), October 2021.
- [2] J. Liu, J. Liu, X. Shi, and M. Honarvarnazari, "Snow and Ice Treatment Products Evaluation", MoDOT Project TR202002 Final Report, Missouri S&T, MO, 2021.
- [3] B. Riad, J. Liu, and X. Zhang, "Implementation the LWD for MoDOT Construction Acceptance of Unbound

- Material Layers”, MoDOT Project TR202103 Interim Report, Missouri S&T, MO, 2021.
- [4] Quesnel, Z. (2022). Low-cycle fatigue behavior of modern and historic grade 40 reinforcing steel bars. MS Thesis. Washington State University, Pullman. WA.
  - [5] Beaujean P.P., “Modeling and Measurement of Rebar Corrosion and Crack Formation Using High Frequency Ultrasonics in Three Dimensions and with No Contact with the Sample”, TriDurLE Year 1 Final Report, January 12, 2022.
  - [6] Kim, Y.J., Pantelides, C.P., Shi, X. *Durability, Service Life, and Long-Term Integrity of Concrete Materials, Bridges, and Structures*. Special Publication SP-351, American Concrete Institute, Farmington Hills, MI. April 2022.
  - [7] Liu, J., Liu, J., Shi, X., Honavar Nazari, M. *Snow and Ice Treatment Products Evaluation*. Report No. CMR-21-009. Prepared for the Missouri Department of Transportation, Jefferson City, MO. December 2021.

## Presentations

TriDurLE researchers presented at the first annual TriDurLE Symposium December 6-7. Instead of listing these separately, view them as listed and recorded at <https://tridurle.wsu.edu/2021-annual-symposium-presentations>.

- [1] Mamun, AA., Romero, P., and Asib, ASM.: Laboratory Simulation of HMA in a Cold Region: An Artificial Intelligence-Based Approach. Paper TRBAM-22-04180. Presented at the 2022 meeting of the Transportation Research Board.
- [2] Xijin Zhang, Yuan Guo, Xudong Fan, Xiong (Bill) Yu, BACTERIA MEDIATED CEMENTATION OF SANDS: POTENTIAL FOR CONCRETE CRACK SEALING (TRBAM-22-03359), TRB 101st annual conference, Washington DC, Jan 9-13, 2022
- [3] Motter, C. and Phillips, A. R. (2022). “Seismic performance of steel and FRP jacketed bridge columns to Cascadia Subduction Zone earthquakes,” WSDOT, January 14, Tumwater, WA. (delivered virtually).
- [4] Motter, C., Phillips, A., Eberhard, M., Berman, J., and Maurer, B. (2021) “Data-Driven Assessment of Post-Earthquake Bridge Functionality and Regional Mobility.” PacTrans Region 10 Transportation Conference, virtual. (oral presentation, virtual poster session).
- [5] Carloni, Christian, Preliminary experimental results of the bond between GFRP bars and concrete, ACI Convention, October 17-21, 2021
- [6] Zhao, J. and Lee, J.Y. Assessing resilience for supply chain systems subjected to multiple risks. 2021 Society for Risk Analysis Annual Meeting, Virtual, December 5-9, 2021.
- [7] Hart, K., Sjurseth, T., and Tazarv, M. (2022) “Precast Bridge Bents with Replaceable Fuses,” *ACI Spring 2022 Convention*, Orlando, FL, Mar. 28.
- [8] Tazarv, M., Won, K., Jang, Y., Hart, K., and Greeneway, E. (2022) “Post-Earthquake Assessment of Bridge Columns Using AI Enabled Computer Vision,” *TriDurLE Webinar*, Washington State University, Mar. 24.
- [9] Tazarv, M., Won, K. (2022). USDOT RD&T UTC Video Forum – Artificial Intelligence and Transportation, Feb. ([Link](#)).
- [10] Tazarv, M., Won, K., Jang, Y., Hart, K., and Greeneway, E. (2022) “AI-Based Damage Assessment of RC Bridge Columns after Earthquakes,” *The 2022 TRB Conference*, Washington, DC, Jan. 11.
- [11] “MODELING COLLAPSIBLE SOIL AND ITS IMPACT ON AXIALLY LOADED PILES” Webinar hosted by National Center for Transportation, Infrastructure Durability & Life-Extension (TriDurLE), January 26, 2022.
- [12] Kim, Y.J. Translation of Research into Practice for Concrete Bridges and Buildings in the United States, The KCI Presidential Lecture Series, virtual, Feb. 15, 2022
- [13] Marshall, Wesley and Coppola, Nick. Evaluating Sidewalk Infrastructure & Prioritizing Investment. TriDurLE Webinar, October 2021.
- [14] Coppola, Nick and Marshall, Wesley. Evaluating Sidewalk Infrastructure & Prioritizing Investment. TriDurLE Virtual Symposium, December 2021.
- [15] Coppola, Nick and Wesley Marshall. Prioritizing Sidewalk Infrastructure: Where Do We Start? Transportation Research Board; Washington, D.C.; January 2022.
- [16] Zhu, H. Wu, Y. Wang, and J. Liu. “Feasibility Study on Foamed Fire-Resistant Coating Materials”, Transportation Research Board (TRB) Annual Meeting, January 9-12, 2022, Washington DC.
- [17] Riad and X. Zhang, “Using a Three-Dimensional Hydro-Mechanical Model to Study the Cyclic Behavior of Unsaturated Soils”, GeoCongress 2022, Charlotte, NC, March 20-23, 2022.
- [18] Riad and X. Zhang, “Using the Modified State Surface Approach to Explain and Simplify the CASM”

- GeoCongress 2022, Charlotte, NC, March 20-23, 2022.
- [19] Chenxi Chen, Xianbiao Hu, and Yang Li. "A Prefix Tree Based, Privacy Budget Allocation Optimization Algorithm for Transit Smartcard Data Publishing with Differential Privacy", TRB Annual Meeting, January 9-12, 2022, Washington DC.
- [20] Fayek, S., and Zhang, X. "Consideration of One Camera Photogrammetry-Based Method to Reevaluate Some Aspects of Conventional Triaxial Methods." GeoCongress 2022, Charlotte, NC, March 20-23, 2022.
- [21] Fayek, S., and Zhang, X. "Evaluating the Effects of Specimen Misalignment during Triaxial Testing Using a Photogrammetry-based Method." TRB Annual Meeting, January 9-12, 2022, Washington DC.
- [22] Galinmoghadam, J., and Zhang, X. "Mitigating Pumping in Pavement Shoulder Using Wicking Geotextile: An Experimental Study." TRB Annual Meeting, January 9-12, 2022, Washington DC.
- [23] H. Wu, Y. Wang, X. Zhang, and J. Liu. "Impacts of Lightweight Aggregates Interlayers for Air Convection Embankment on Pavement Thermal Profile and Pavement Performance in Alaskan Permafrost Regions", TRB Annual Meeting, January 9-12, 2022, Washington DC.
- [24] J. Liu, "Impact of Lightweight Aggregates Interlayers for Air Convection Embankment on Pavement Performance in Permafrost Regions", Keynote Speech, Transportation Research Congress 2021, November 5-7, 2021 (virtual).
- [25] J. Liu, "Integrating Quality Assurance in Balanced Mix Design for Durable Mixtures", CI&CRC Joint Conference, Arlington, VA, March 9 -12, 2022.
- [26] J. Liu, "Integrating Quality Assurance in Balanced Mix Design for Durable Asphalt Mixture", TriDurLE webinar, November 19, 2021.
- [27] J. Liu, "Preliminary Study of HDPE Modified Asphalt", CI&CRC Joint Conference, Arlington, VA, March 9 -12, 2022.
- [28] J. Liu, "The Use of Low-Density Cellular Concrete for Air Convection Embankment to Protect Permafrost Foundations in Cold Regions", Lightweight Fill Conference, October 19-21, 2021 (virtual).
- [29] J. Liu, "Use of Cellular Concrete for Air Convection Embankment to Protect Permafrost Foundations in Cold Regions", 5th International Conference on Transportation Infrastructure and Materials, October 21-22, 2021 (virtual).
- [30] J. Liu, "Use of Lightweight Deflectometer for Construction Quality Assurance", Transportation Research Congress 2021, November 5-7, 2021 (virtual).
- [31] J. Galinmoghadam, J. Liu, X. Zhang, C. Lin, and Y. Guo. "Mitigating Pumping in Pavement Shoulder Using Wicking Geotextile: An Experimental Study", TRB Annual Meeting, January 9-12, 2022, Washington DC.
- [32] J. Wei, Y. Cheng, K. Chen, M. Wang, C. Ma, and X. Hu. "Non-Linear Model-Based Subway Station-Level Peak Hour Ridership Prediction Approach in the Context of Peak Deviation", TRB Annual Meeting, January 9-12, 2022, Washington DC.
- [33] J. Liu, and J. Liu. "Prediction Models for Low-Temperature Creep Compliance of Asphalt Mixtures Containing Reclaimed Asphalt Pavement (RAP)", TRB Annual Meeting, January 9-12, 2022, Washington DC.
- [34] Q. Tang, and X. Hu. "A Merging-Based, Multi-State Analytical Model for Operation Design Domain of Autonomous Vehicles in Work Zones on Two-Lane Highways", TRB Annual Meeting, January 9-12, 2022, Washington DC.
- [35] Riad, B., and Zhang, X. "Full Characterizing the Elasto-Plastic, Hydro-Mechanical, Cyclic Behavior of Unsaturated Soils Using Constant Water Content Oedometer and Direct Shear Tests." TRB Annual Meeting, January 9-12, 2022, Washington DC.
- [36] Wu, H. "Impacts of Lightweight Aggregates Interlayers for Air Convection Embankment on Pavement Thermal Profile and Pavement Performance in Alaskan Permafrost Regions." Presented at 2021 Midwest Numerical Analysis Day (MWNADay), October 29-30, 2021, Rolla, MO.
- [37] Wu, H. "Impacts of Lightweight Aggregates Interlayers for Air Convection Embankment on Pavement Thermal Profile and Pavement Performance in Alaskan Permafrost Regions." the 12th IACIP Annual Workshop, January 9, 2022.
- [38] X. Zhang. "Recent Advances in Measuring Full field Displacements of Soil Specimen during Triaxial Testing." TRB Annual Meeting, January 9-12, 2022, Washington DC.
- [39] X. Zhang. "Recent Advances Measuring Volume Change during Triaxial Testing", TRB AG40-Mechanics and Drainage of Saturated and Unsaturated Geomaterials Committee Meeting, January 10, 2022.
- [40] X. Zhang. "Working Mechanism of a New Wicking Geotextile in Roadway Applications: A Numerical Study", TRB AG30-Geosynthetics Committee Meeting, January 10, 2022.

- [41] X. Zhang. “Working Mechanism of a New Wicking Geotextile in Roadway Applications: A Numerical Study”, TRB AKG80-Geo-Environmental and Climatic Impacts on Geomaterials Committee Meeting, January 12, 2022.
- [42] XB Hu, “Predicting Asphalt Pavement Roughness with an Ensemble Learning Approach”, the 1st International Data Science for Pavements Symposium, McLean, VA, March 22-24, 2022.
- [43] Xia, X., and Zhang, X. “A Table Method for Coded Target Decoding with Application to 3-D Reconstruction of Soil Specimens during Triaxial Testing.” TRB Annual Meeting, January 9-12, 2022, Washington DC.
- [44] Xia, X., and Zhang, X. “Use of Low-Cost Surveillance Cameras to Continuously Measure the Volume-Changes of Soil Specimen during Triaxial Testing.” Geo-Congress 2022, March 20-23, 2022, Charlotte, North Carolina.
- [45] Xianbiao Hu. “Autonomous Vehicles for Roadway Infrastructure Maintenance (CAV for Work Zone)”, the 24th Chinese Overseas Transportation Association (COTA) Winter Symposium session 2: the Evolution of Connected and Autonomous Vehicle Technology. Jan 10, 2022.
- [46] Y. Song, Y. Wang, X. Hu, and J. Liu. “An Efficient and Explainable Ensemble Learning Model for Asphalt Pavement Condition Prediction Based on Long-Term Pavement Performance Dataset”, TRB Annual Meeting, January 9-12, 2022, Washington DC.
- [47] Zhang, X., “A Photogrammetry-Based Method to Measure Full-Field Displacement of Soil Specimens during Triaxial Testing.” Keynote Speech at the Transportation Research Congress, November 5-7, Hangzhou, China (Virtual).
- [48] Zhang, X., “Recent Advances in Measuring Volume of Soil Specimen in Triaxial Testing.” Keynote Speech at 5th International Conference on Transportation Infrastructure and Materials, October 21-22, 2021 (Virtual).
- [49] Wen, Haifang, First Annual Symposium Annual Symposium of National Center for Transportation Infrastructure Durability and Life-Extension: “Test Methods and Bond Performance Characterization of Shotcrete-Concrete Interfaces
- [50] Akinleye, T.O., Hohner, A.K., Shi, X., Akin, I.D. Influence of Electrochemical Remediation on the Hydraulic and Mechanical Behavior of a Metal-Contaminated Clayey Soil. Proceedings of Geo-Congress 2022, March 20–23, 2022. Charlotte, NC.
- [51] Shi, X. Graphene Oxide as a Carbon-Based Nanomaterial that Enables Fly Ash Geopolymer Concrete. Invited Presentation by the Department of Civil & Environmental Engineering, FAMU-FSU Engineering, Feb. 25, 2022. Online.
- [52] Shi, X., Li, J.Y. Ongoing WSU Work in the Nexus of Transportation and Climate. Keynote Presentation for the 1st International Workshop on Resilient Infrastructure. International Joint Research Center for Resilient Infrastructure, Tongji University, Nov. 13, 2021. Online.
- [53] Shi, X., Li, Z. Synergy of Graphene Oxide and Nanoclay to Benefit the Performance of a Silicate-Based Sealer for Concrete. Keynote Presentation for the 5th International Conference on Transportation Infrastructure and Materials (TIM 2021), Oct. 21, 2021. Online.
- [54] Shi, X. Selected WSU Work in the Transportation – Climate Nexus. A presentation invited by the WSU Office of Research, October 20, 2021, Pullman, WA.
- [55] Shi, X. Selected Sensing Topics from the Smart and Green Infrastructure Group at WSU Pullman. Invited Presentation for the METER Group, Pullman, WA, Oct. 14, 2021.
- [56] Deng, Y., Shi, X. Developing Enhanced Performance Curves for ITD Asphalt Pavements. Presentation for the UI – ITD Research Progress Meeting, October 29, 2021, online.
- [57] He, J., Shi, X., Mesarovic, S. Durability of Highly Flowable Self-Healing Concrete under Freeze Thaw Actions. An online presentation at the ACI Fall Convention, Atlanta, GA, Oct. 17, 2021.
- [58] Li, Z., Shi, X. Effect of Graphene Oxide on the Properties of a Fly Ash-Based Geopolymer Paste Before and After F/T Damage. An online presentation at the ACI Fall Convention, Atlanta, GA, Oct. 17, 2021.

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

#### SDSU Project Websites

Post-Earthquake Serviceability of RC Bridge Bents Using Visual Inspection

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

Drone-Based Measurements for Bridge Field Testing,

<https://sites.google.com/people.unr.edu/mostafa-tazarv/research/drone-based-measurement>

Repairable Precast Bridge Bents for Extreme Events

<https://sites.google.com/people.unr.edu/mostafa-tazarv/research/repairable-bridge-bents>

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

### 3.3 Technologies or techniques

- Florida Atlantic University has developed Nonlinear Parameter Optimization. A non-linear solver using the Trust-Region Reflective (TRR) algorithm is used to match a set of synthetic data to the Biot-Stoll model. Synthetic data is produced separately using set values in a script that functions purely as a table of constants. The synthetic pulse is then fed these constants and uses the Biot model for sound propagation in a porous medium to create a fake signal that the model can be ran against to test for accuracy.
- Dr. Christian Carloni of CWRU has developed a new testing method that features a notched beam with multiple notches and a bar embedded to study the opening of cracks
- CWRU has developed a self-healing concrete using microorganism

### 3.4 Inventions, patent applications, and/or licenses

- Dr. Xiong Yu of CWRU has filed an invention disclosure on his self-healing concrete technology
- Shi, X., Zhong, J. Graphene oxide fine aggregate in cement composites. Non-provisional patent filed on April 19, 2022.

### 3.5 Other output

University of Utah has generated a software program in which corrosion of columns can be modeled using open source software to study the seismic performance of corroded columns constructed with accelerated bridge construction methods.

## 4. OUTCOMES

### 4.1 Increased understanding and awareness of transportation issues

Dr. Wesley Marshall's completed year one research project on sidewalk infrastructure will help researchers and municipalities in their collection of sidewalk metrics so that they can improve their asset management capability and better prioritize investments in sidewalk infrastructure.

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

Nothing to report

### 4.3 Increases in the body of knowledge

University of Utah's collaboration between universities has enhanced the modeling capabilities for corrosion initiation and evaluation of the seismic performance of corroded columns. This is expected to increase the body of knowledge and the existing state-of-the art. the collaborative project between three different universities has allowed for an improved process to develop asphalt mixtures that are capable of balancing the need for mechanical performance and durability. This is referred to as balanced mix design. The project has also produced increases in the body of knowledge, improvement of existing techniques, practices, and technologies. The development and testing of an underground stormwater detention system using permeable cellular concrete (PLCC) as one of the system's primary components. We will focus on developing this technology for urban areas or other situations where roadway right-of-way and other conditions (high flooding hazard, soft ground conditions, buried utilities, adjacent infrastructure, etc.) limit or restrict the use of "conventional systems."

At UC Denver, the computational approach, agent-based modeling, was taken from computational sociology, which is new in civil structures. This cross-disciplinary effort will thus enhance the body of knowledge and guide researchers and practitioners to more efficient and effective ways for understanding the durability of highway bridges.

Dr. Wesley Marshall's work increases the usefulness of remote sensing technologies for measuring and understanding the provision of sidewalk infrastructure in cities. The idea is to assist the research community in developing better sidewalk-related infrastructure da on small study areas due to inadequate. Our research will help facilitate larger and

better research studies.

Dr. Haifang Wen of WSU: The concrete-shotcrete interface study specifically focuses on the interface bond performance than the individual material performance with respect to short term tensile and shear strength and long-term frost resistance for varying substrate surface preparation techniques. Such a detailed analysis on the bond has not been conducted before for shotcrete-concrete bi-material interfaces. Results indicate that the fracture energy is a more sensitive parameter to the variations in the surface preparation technique than bond strength (shear or tension).

#### **4.4 Improvement of existing techniques, practices, technologies**

UC Denver reports that In addition to the agent-based modeling method, the principle of percolation and cellular automata are incorporated. These mathematical approaches will lead to better understanding the complex problems associated with the durability of ABC columns.

Dr. Wesley Marshall of UCD reports that data specific to sidewalk infrastructure has long been deficient. Our research shows that recent advances in remote sensing and planimetric data gives us the ability to accurately measure sidewalk presence and width. This new resource for sidewalk data, combined with our methods for measuring sidewalk metrics, will provide cities with improved aptitude for asset management, prioritizing investments in sidewalk infrastructure, and improving upon disparities in sidewalk access.

#### **4.5 Enlargement of the pool of trained transportation professionals**

TriDurLE has implemented a number of initiatives to assist in and help fun students to work in TriDurLE laboratories, as stated previously. Several TriDurLE universities are graduating doctoral and master's degree students who have been conducting research and receiving training by TriDurLE faculty (see earlier sections). These graduates will help enlarge the pool of trained transportation professionals.

#### **4.6 Incorporation of new techniques, practices, technologies**

Nothing to report

## **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?**

Nothing to report

#### **5.2 What is the impact on other disciplines?**

Dr. Wesley Marshall, whose year one project is complete, reported that his research on sidewalk infrastructure highlights the benefits of secondary sidewalk data based on remotely sensed planimetric data to asset management and transportation planning. Results also shed light on where cities could start in terms of prioritizing sidewalk infrastructure.

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

Several TriDurLE universities are taking their research projects to the classroom. For example, Dr. Wesley Marshall's research at UCD was integrated into a "GIS and Transportation" graduate course, which provided students the opportunity to get involved in data collection and analysis. The research at 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 needs tools and guidance as to the management of the pavement infrastructure to gain decades of

service life beyond is presently realized. Other research, yet to be realized, will have significant impacts.

#### **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.

UC Denver's Dr. Wesley Marshall hopes that efforts in terms of technology transfer with multiple presentations will help researchers and municipalities in their efforts towards improving sidewalk data.

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

The underlying goal of Dr. Wesley Marshall's research on better sidewalk data is to improve sidewalks, one of our most fundamental and under-researched infrastructures. This will help improve mobility, safety, equality and accessibility.

The AI-based computer vision bridge serviceability assessment tool developed at SDSU is expected to help the 16 seismic-prone states of the nation to quickly and safely evaluate affected bridges after earthquakes, which will save time, costs, and lives. The repairable RC bridge column detailing allows quick (e.g., a few hours) and low cost (e.g., use of a few bars or tendons) repair of RC bridge columns. The detailing, which was found feasible and robust, has combined the benefits of accelerated bridge construction (ABC) with low-damage and repairable detailing. Structural displacement measurement at sub-millimeter accuracy using drones is novel and can revolutionize bridge field testing by eliminating conventional sensors.

## **6. CHANGES/PROBLEMS**

#### **6.1 Changes in approach and reasons for change**

Given that laboratory situations at partner universities are still uncertain due to the pandemic, experimental components will be added and tasks will be conducted at the University of Colorado Denver. MST reported that the pandemic continued to significantly impact the research progress during this reporting period. Significant delay has been caused in conducting research and delivering results because of lack of staff, restraints in lab use and field work, delays in project set-up, etc. Time extension was requested and approved for project completion. Other consortium universities reported changes and adjustments in procedures due to COVID delays.

#### **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 filed for no-cost extensions due to these delays and research projects will be completed by the new research timelines submitted.

#### **6.3 Changes that have a significant impact on expenditures**

CWRU reports that the cost of materials (wood and steel) has reduced the ability to perform additional tests.

#### **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 A

Table B1. Year 2 research projects. For project details, see [TriDurLE.wsu.edu/research](https://TriDurLE.wsu.edu/research)

| Research Project                                                                                                                                    | PIs and Co-PIs                                  | University                                                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|------------------------------------------------------------|
| Using Deep Learning for Accurate Detection of Bridge Performance Anomalies                                                                          | Farnoush Banaei-Kashani<br>Chris Pantelides     | University of Colorado Denver<br>University of Utah        |
| Design of Fly Ash-based Geopolymer Concrete-filled FRP Tube Composite for Highly Durable and Environmentally Friendly Infrastructure                | Xianming Shi                                    | Washington State University                                |
| Developing High-performance Nanocomposite Coating for Steel Reinforcement Protection in Chloride-rich Concrete                                      | Xianming Shi                                    | Washington State University                                |
| Development of Microcapsule-based Self-healing, High-strength Engineered Cementitious Composites (SHHS-EE)                                          | Xianming Shi<br>Liang Fan                       | Washington State University                                |
| Sustainable nHPC Mixtures for Durable Overlay of Concrete Bridge Decks in Cold Regions: Proof of Concept                                            | Xianming Shi                                    | Washington State University                                |
| Development of Stormwater Detention/Infiltration System for Urban Highways Using Permeable Lightweight Cellular Concrete, Phase I                   | Steven Bartlett<br>Nigel Bruce Pickering        | University of Utah<br>Washington State University          |
| Preparation of Pavement Infrastructure for Connected and Autonomous Vehicle Deployment – Phase I                                                    | Xianbiao Hu<br>Jenny Liu                        | Missouri University of Science & Technology                |
| Drone-based Measurements for Bridge Field Testing                                                                                                   | Mostafa Tazarv<br>Marco Ciarcia<br>Kwanghee Won | South Dakota State University                              |
| Development of Holistic Methodologies for Improving Asphalt Mix Durability (Yr. 2)                                                                  | Jenny Liu<br>Pedro Romero<br>Fujie Zhou         | Missouri S&T<br>University of Utah<br>Texas A&M University |
| Performance of ABC Columns Cost-effective Retrofit Strategies Subjected to Synergistic Distress Resulting from Corrosion and Seismic Loading (Yr 2) | Yail Jimmy Kim<br>Chris Pantelides              | University of Colorado Denver<br>University of Utah        |
| Seismic Performance and Fragility of Retrofitted Reinforced Concrete Bridge Columns to Long-duration Earthquakes                                    | Adam Phillips<br>Chris Motter                   | Washington State University                                |
| Assessment and Evaluation of Post-liquefaction Lateral Spread Impact on Bridge Deep Foundations                                                     | Mohamad Ashour<br>Sudip Bhattacharjee           | Alabama A&M University                                     |
| Use of Recycled Plastics in Asphalt Pavement (Yr 2)                                                                                                 | Jenny Liu<br>Xinhua Liang                       | Missouri S&T                                               |
| AI-based Prediction Models for Transportation Infrastructure Asset Management Data Hub – Phase I                                                    | Xianbiao Hu<br>Jenny Liu                        | Missouri S&T                                               |
| Effects of Combined Carbonate and Biofilm on Shrinkage Cracking in Unsaturated Cementitiously Stabilized Soils Using Microcapsules                  | Xianming Shi                                    | Washington State University                                |
| Repairable Precast Bridge Bents for Extreme Events                                                                                                  | Mostafa Tazarv                                  | South Dakota State University                              |
| UAV-enabled Structure-From-Motion Photogrammetry for Bridge Crack Detection and                                                                     | Xiong Zhang<br>Jenny Liu                        | Missouri S&T                                               |

|                                                                                                                   |                                       |                                                           |
|-------------------------------------------------------------------------------------------------------------------|---------------------------------------|-----------------------------------------------------------|
| Characterization                                                                                                  | Genda Chen                            |                                                           |
| A Multiple-camera System to Determine the Absolute Volume of Soil Specimen During Dynamic Triaxial Testing (Yr 1) | Xiong Zhang<br>Jenny Liu              | Missouri S&T                                              |
| The (In)Equitable Distribution of Quality Bicycling Infrastructure                                                | Wesley Marshall<br>Nicholas Ferenchak | University of Colorado Denver<br>University of New Mexico |
| Durability of Transverse Sawcut Joints in Midwestern Jointed Concrete Pavements                                   | Dan Zollinger<br>Jenny Liu            | Texas A&M University<br>Missouri S&T                      |
| Development of Infrastructure Research Weekly APP                                                                 | Xianming Shi<br>Kakan Dey             | Washington State University<br>West Virginia University   |
| Developing Enhanced Performance Curves of ITD Asphalt Pavements by Mining the Historical Data                     | Xianming Shi                          | Washington State University                               |
| Comparing the Performances of Different Wicking Fibers for Water Removal for Transportation Applications          | Xiong Zhang<br>Xinhua Liang           | Missouri S&T                                              |
| Corrosion Propagation Monitoring Legacy Samples and Forensic Analysis on Selected Sample                          | Francisco Moreno-Presuel              | Florida Atlantic University                               |
| Poro-Elastic Modeling and Measurement of Rebar Corrosion and Crack Formation Using High Frequency Ultrasonics     | Pierre-Phillipe Beaujean              | Florida Atlantic University                               |
| Upcycling agro wastes as additions for sustainable roadway anti-icing operations                                  | Xianming Shi                          | Washington State University                               |