# University of Pittsburgh Transportation Research

The following are short descriptions of completed and ongoing transportation research projects being conducted by the University of Pittsburgh Civil and Environmental Engineering faculty. It includes research being conducted under Pitt’s Center for Sustainable Transportation Infrastructure (CTSI), and the Impactful Resilient Infrastructure Science and Engineering (IRISE) consortium, including an agreement with the Pennsylvania Turnpike Commission to conduct several research projects under the banner of the Mon-Fayette Expressway Test Bed initiative.

## Bridges

### Completed Research

1. **Steel Bridge Corrosion Prevention and Mitigation Strategies**: This report provides a comprehensive literature review that highlights important issues related to corrosion in steel bridges with the objective of identifying shortcomings in current practice in Pennsylvania and identifying novel methods for further study and/or possible implementation. Promising corrosion prevention, mitigation and repair solutions are recommended.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Completed/>

1. **Improving Bridge Assessment Through the Integration of Conventional Visual Inspection, Non-Destructive Evaluation and Structural Health Monitoring Data:** This study established a framework capable of leveraging emerging Structural Health Monitoring (SHM) and Non-Destructive Evaluation (NDE) techniques to provide improved performance assessment of bridges.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Completed/>

1. **Corrosion Repair Strategies for Steel Girder Ends Using High Performance and Traditional Materials:**  This project developed and evaluated practical repair strategies for a range of girder geometries and corrosion levels using traditional as well as high performance materials (including ultra-high performance concrete).
2. **Data Management, Mining, and Inference for Bridge Monitoring:** The purpose of this project was to investigate advanced data management, analysis, mining and inference approaches for health monitoring, safety evaluation, reliability, and resilience assessment of instrumented bridges in Pennsylvania.
3. **Integrating Additive Manufacturing with Accelerated Bridge Construction Techniques:** This project is exploring the feasibility of integrating additive manufacturing with ABC techniques in Pennsylvania. The focus is on identifying, fabricating and mechanically testing a range of 3D printable prefabricated bridge elements currently used in ABC projects.

### Ongoing Research

1. **A Novel Methodology for Structural Optimization of Bridge Decks Against Corrosion**: This project will create and deploy a novel toolset for the prediction of corrosion based on the structural features of a selected bridge deck. It will identify the complex interrelationships between the temporal and spatial frequency of salt application and the corrosion mitigation strategies in place. This information will be combined with reliability-based optimization to provide guidelines for the operational control of bridge decks subject to corrosion mechanisms.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Bridge Load Ratings:** This project addresses the challenge of increasing bridge postings and closures due to aging infrastructure and growing load demands. The primary objective is to create digital twins of selected Pennsylvania concrete tee beam bridges, employing commercial finite element (FE) software like ANSYS. These bridges will be analyzed using both detailed numerical models and simplified representations that simulate an automated process. The aim is to assess whether current load ratings, which lead to conservative postings, are justified. By comparing the results and evaluating them against the Bridge Safety Inspection Manual Publication 238, 2022 Edition, this project intends to determine the validity of bridge postings and, if necessary, develop a software tool to supplement current analysis methodologies. The project's outcomes will include accurate FE models based on engineering drawings, insights into the appropriateness of current load ratings, and the potential creation of a software tool to enhance bridge load rating practices.

## Geotechnical and Stormwater

### Completed Research

1. **Identification of Factors Controlling the Development of Subsidence Impacts Forecasting Methodology to the I-70 Alignment over Longwall Mining of the Tunnel Ridge Mine, Washington County, Pennsylvania:** In the winter of 2019, the Tunnel Ridge Mine extracted a longwall panel under I-70 in Washington County, PA. Additional longwall panels under other portions of the highway are planned in the future. The extraction of these panels can produce a subsidence basin with maximum surface drops from 4 to more than 5-ft, the majority of which occurs within one or two months of undermining the roadway. This project investigated the influence of longwall mining on highway alignments and associated slopes and embankments, evaluated how the highway deforms during undermining with a focus on determining its transient characteristics, utilized models to better understand subsidence impacts to the highway alignment, and where possible, determined how other future highway alignments could be impacted.

Website Link: <https://www.engineering.pitt.edu/subsites/centers/csti/projects/research-expertise-and-capabilities/developing-ideas/>

1. **Exploring Approaches to Managing Landslide Risks: Summary Report:** 121 individuals representing over 40 organizations in the public, private and academic sectors participated in a workshop aimed at developing consensus on needed landslide research and development activities that will help state and local transportation systems direct their limited resources to the highest risk problem areas.

Website Link: <https://www.engineeringx.pitt.edu/Sub-Sites/Consortiums/IRISE/_Content/Achievements/Products/>

1. **Landslide Capacity Building Seminars:** Approximately 400 professionals and students participated in a series of three seminars devoted to the topics of 1) landslide recognition and monitoring and 2) new technologies. The seminar series provided an opportunity for professionals to interact with each other and served to engage and familiarize participating students with problems and solutions.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Events/>

1. **Depth to Bedrock Seismic Measuring Device**: The purpose of this project is to evaluate the use of passive seismic methods to estimate the depth to bedrock. The accuracy and efficacy of these methods are being compared to current and historic core borings taken by PennDOT with the goal to eliminate a portion of the borings currently being performed by the Department.
2. **Landslide Best Practices:**  A best practices compilation document has been prepared that has: (a) Identified class/types of landslides impacting Southwestern Pennsylvania; (b) Identified corrective actions taken for each landslide class/type; and (c) Identified challenges in design procedures and permitting processes, including recommended revisions to design specifications.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Completed/>

1. **A Seminar Series on Innovative and Comprehensive Stormwater Management to Produce Multiple-Benefits in the Appalachian Plateau:** A series of seminars will be held at the University of Pittsburgh to share collective and emerging knowledge about storm water control technologies, particularly green infrastructural approaches, effective cross-jurisdictional strategies, and scenarios of climate and regulatory strategy fundamental to successful management of stormwater challenges.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Completed/>

### Ongoing Research

1. **Development of a Regional Landslide Inventory to Advance Hazard and Risk Estimates for Southwestern Pennsylvania:** This project is: (a) Designing a structure for a unified inventory of landslides that addresses the needs of stakeholders; (b) Initiating a data collection effort focused on historical landslide observations to establish a working database and document workflows that enable the collection, sharing, and analysis of new data across agencies; (c) demonstrating the power of comprehensive data through evaluation of collected data.

Website Link: [https://www.engineering.pitt.edu/subsites/consortiums/irise/research/active-](https://www.engineering.pitt.edu/subsites/consortiums/irise/research/active-projects/) projects/

1. **Analysis of Reoccurring Landslides in SWPA to Advance Hazard and Risk Estimates:** The project will examine landslide reoccurrence in southwestern Pennsylvania and its interaction with human landscape modifications. By analyzing regional landslide data and conducting spatial analysis, the project seeks to identify patterns and develop mechanistic models of reoccurrence. Multivariate analysis will compare environmental factors between reoccurring and stable/new landslides. The results will identify high-risk areas, guiding mitigation efforts and informing effective repair methods in landslide-prone areas.

Website Link: [https://www.engineering.pitt.edu/subsites/consortiums/irise/research/active-](https://www.engineering.pitt.edu/subsites/consortiums/irise/research/active-projects/) projects/

1. **Advancing** **Regional Comprehensive Stormwater Management through Cross-Jurisdictional Coordination and Cooperation:** The project will develop a series of coordinated stormwater meetings ranging from lunch-and-learn training sessions to a full blown second Symposium. These meetings would vary in scope but be aligned in purpose to address the challenges identified in the 2023 Symposium. We envision three primary objectives: 1) Coordination of a series of lunch time training session on pertinent stormwater topics.; 2) A series of consensus building meetings between transportation professionals, local officials, and the wider stormwater community to examine the stormwater regulation landscape and determine best practices that could improve stormwater management in cross-jurisdictional infrastructure.; and 3) A Year 7 stormwater symposium to maintain momentum in these stormwater conversations.

## Pavements and Materials

### Completed Research

1. **Toward Using Microbes for Sustainable Construction Materials: A Feasibility Study:** This study evaluated the feasibility of increasing the durability, resiliency and sustainability of reinforced concrete structures by using microbes to provide self-healing properties to prevent water and chloride ingress through structural and/or environmental cracking.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Completed/>

1. **Development of Simplified Mechanistic-Empirical Design Tool for Pennsylvania Rigid Pavements:** To accelerate the implementation of the AASHTO Mechanistic-Empirical Pavement Design Guide in Pennsylvania, a simplified design method and a localized design tool for concrete pavements were developed. The new procedure, PittRigid ME restricts design input parameters to the most influential and relevant for Pennsylvania conditions and matches the MEPDG predicted performance at a fraction of the computational cost.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Completed/>

1. **Material Compatible Repairs for Concrete Pavements and Bridge Decks:** This study investigated the effects of the incompatibility between the repair and existing concrete through a laboratory investigation and a computational study. A methodology was established for developing a performance engineered repair material to be used for performing a material compatible repair.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Completed/>

1. **Carbon Nanotube Additives for Structural and Highway Concrete:** This study investigated the potential to enhance the density, tensile strength, durability, abrasion resistance, and shrinkage reduction of concrete and pavements by including carbon nanotubes in the mixture. We performed a comprehensive literature review to inform the experimental plan, which included different carbon nanotube chemistries, wt% additives, and ASTM standard testing of 4” by 8” cylindrical concrete specimens.
2. **Super Load Effect on Pavement Life:** This project will capture how to assess distress and damage caused by superloads to pavements in Pennsylvania, include recommendations for increased design loads, better design methodologies, different pavement thickness or type to handle these concentrated loads and suggestions for changes to Department standards and specifications.
3. **Early Opening of Concrete Pavements to Traffic:** An innovative mechanistic-based procedure for quantifying the risk of premature failure and long-term damage caused by traffic opening at various concrete strength levels is being developed.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Completed/>

1. **Preliminary Evaluation of Pavement Surface Distresses Related to Pavement Markings:** This project is investigating whether pavement markings are causing pavement surface deterioration and, if so, will develop approaches for mitigation of the problem.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Completed/>

1. **Three-dimensional Micro-mechanical Characterization of the Effect of Vibration and Compaction in Concrete Pavements:** This project will create a set of guidelines to provide for more efficient construction of new pavements. It will explore advances in the description of the effects of vibration and compaction procedures that could lead to the definition of practical rules to perform optimized paving under different conditions.

### Ongoing Research

1. **Joint Design Optimization:** This research includes evaluating the type, reservoir design, construction practices and performance of joint sealant in Pennsylvania and providing guidance on strategies for optimizing joint performance. The current reservoir design process is based on an empirical relationship established for conventional jointed plain concrete pavements (JPCP). With the availability of strain data from instrumented pavement structures currently in service, these old methodologies will be re-evaluated and, if needed, new joint design strategies/guidelines will be developed.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Material Compatible Repairs Evaluation:** This project will assess the performance of partial depth repairs made using the recommendations developed under the predecessor research project in comparison with partial depth repairs made using other methods in similar settings. Concurrently, for the same repairs, the project will investigate the ability of ultrasonic tomography testing to provide reliable information for required partial depth repair dimensions and for evaluating bond condition after repair placement.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Continuation of Carbon Nanotube Additives for Structural and Highway Concrete:** The purpose of this project is to evaluate the use of carbon nanotubes (CNTs) in concrete and pavement to increase the density, tensile strength, durability, abrasion resistance, and shrinkage reduction for structural and pavement concrete. A comprehensive literature review will be conducted to establish the material variables to be explored (e.g., type of CNTs and range of CNT loading) in the experimental design as well as the reported benefits of CNTs in concrete. A laboratory investigation into the effect of CNTs on the performance of concrete mixtures versus traditional PennDOT concrete mixtures will be conducted and the benefits evaluated. Recommendations relative to the feasibility of incorporating CNT technology for PennDOT concrete mixtures as well as any potential benefits or disadvantages will be made
2. **Microbial Concrete Sealer:** The objective of this project is to investigate the feasibility and define the testing procedure and regimen effectiveness of applying a bio inspired mortar capable of producing Microbially Induced Carbonate Precipitation (MICP) to mitigate the deterioration of deck, parapet, and substructure concrete. The research will include identifying the health and safety issues, effects on the concrete properties, and conducting minor pilot testing to evaluate parameters to be examined.
3. **Prediction of Dowel Corrosion and Effect on Performance of Concrete Pavements:** In this project, the development of corrosion on metallic dowels in concrete pavements will be quantified as a function of critical environmental and design parameters. Critical factors identified through modeling will be used to design a laboratory investigation that will evaluate the loss of dowel performance as a function of corrosion development. Results from the laboratory investigation will be used to develop predictive performance models and guidelines for pavement design and management will be developed.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Developing Lightweight and High-Performance Metamaterial Concrete:** This project will develop a suite of metamaterial Light-Weight Concrete (LWC) systems with tunable compressive strength and ductility. A range of selected metamaterial lattices will be 3D printed and applied using two design strategies that can be readily translated into practice. Extensive numerical and experimental studies will be performed to evaluate and predict the mechanical properties of LWC cubes and beams reinforced by the MM lattices.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Seal Coat for Asphalt Pavements: Best Practices and Experience:** develop material selection, construction, and inspection guidelines for successful and uniform use of seal coats in Pennsylvania. This will involve gathering both positive and negative experiences with seal coats from various Departments of Transportation and experienced contractors from different parts of the US (United States) and contrasting these experiences with current Pennsylvania practices with emphasis on the “dos and don’ts” regarding seal coat design, construction and inspection.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Design and Construction of Two-lift Concrete Pavements for Pennsylvania:** This project will focus on the design, construction and evaluation of an experimental two-lift concrete pavement in Pennsylvania. Different concrete mixes for both the high-quality surface layer and the economical-sustainable bottom layer will be proposed and evaluated. The construction of the experimental section focusing on the challenges of working consecutively with two pavers and two concrete mixes will be assessed, a comprehensive evaluation of the bonding conditions between the two layers will be performed and documented, and the potential cost saving and reduction in carbon footprint evaluated.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Adaptation of a Large Language Model for Facilitating Pavement-Related Information Retrieval and Knowledge Discovery:** This project seeks to develop a specialized Artificial Intelligence (AI) model tailored to the field of pavement engineering. The primary objectives of this project are to create an AI model capable of providing swift and accurate responses to common pavement-related inquiries, covering a wide range of topics such as pavement design, construction best practices, maintenance, and testing. Additionally, the AI model will be designed to deliver interactive training, assess user knowledge, and offer valuable feedback, making it an effective tool for skill development and evaluation. Furthermore, the model will assist pavement engineers in efficiently retrieving and summarizing relevant information from a substantial corpus of pavement-related literature. This capability will not only facilitate knowledge discovery but also keep pavement engineers up to date with the latest developments in their field. The project will involve fine-tuning the AI model using an extensive dataset of relevant text, ultimately creating a valuable resource for professionals in the pavement engineering domain.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Self-heating Pavement Systems and Surface-Mounted Heating Elements**

The project will address the costly and environmentally damaging methods of snow and ice removal on roadways by conducting a feasibility study on implementing surface-mounted heating elements for automated snow and ice removal. Unlike existing self-heating concrete systems, this technology will electrify the pavement's surface, reducing the need for deicing chemicals and allowing for both new and existing pavements to be equipped with this capability.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Concrete Mixtures with Half the Carbon Footprint:** The objective of this research is to identify and evaluate alternatives that could be used to reduce the carbon footprint of a PennDOT concrete paving mixture in half. In this project, the use of more sustainable concrete paving mixtures will be investigated. Locally available industrial by-products that could potentially be used in the concrete mixture will be investigated for potential inclusion in the study.

## Worker Safety

### Completed Research

1. **Remote Controlled Technology Assessment for Safer Pavement Construction and QA/QC:** This project is identifying and reviewing new and emerging remote-controlled processes recently developed in the U.S. and abroad. The focus is on identifying potentially implementable technologies that will enable safer and more effective pavement construction and evaluation.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Investigating New Underground Utility Location Technologies and Novel Methods to Improve the Safety and Efficiency of Highway Construction:** This project has investigated current and emerging technologies that could more accurately determine lateral position and depth of known and unknown utilities to improve safety and optimize schedules for highway construction. It has developed requirements for the equipment and test protocols for data collection and data analysis.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Identifying Major Causes of Construction Accidents for the Paving Industry in Pennsylvania:** Dangerous scenarios related to highway and street construction in Pennsylvania have been identified and ranked. Recommendations for avoiding or minimizing dangerous scenarios in the future and for improvement of safety training and development of safety-related equipment have been developed.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

### Ongoing Research

1. **A Novel Immersive Virtual Reality Platform for Health & Safety Training of Construction Workers:** develop an interactive and immersive training platform using Virtual Reality (VR) to train construction workers, inspectors and other project site staff about the dangers caused by runovers, back overs, caught-in or -between, and struck-by accidents in the highway construction industry. The novel platform will immerse users into a detailed digital reproduction of a given construction site that will materialize a selected Health & Safety training module in an immersive environment, while directing the user's attention to hazards randomly placed inside the simulation.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Supervised Learning for Classification of High-Resolution LiDAR Point Clouds:** This project aims to enhance the efficiency of civil infrastructure surveying through the development of advanced software tools. These tools are designed to streamline the handling of dense LiDAR point clouds, simplifying the management of 3D data. The primary objectives of this project include the development of machine learning algorithms to classify and segment 3D scenes, the utilization of computer vision techniques for working with 2D views derived from 3D models, and the assessment of the advantages of integrating color information (RGB) into the analysis. Furthermore, the project aims to create algorithms that preserve point cloud resolution while effectively identifying structural elements, ultimately aiming to expedite and simplify the surveying process for civil engineering projects.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **AI Safety Assistant:** This project will develop an AI/LLM tool to aid safety personnel in the highway construction industry. The tool will focus on two primary tasks: firstly, it will assist in procuring daily work activity plans with a safety focus, aiding safety management in communicating specific hazards associated with various activities and inspection practices. Secondly, as an auxiliary feature, the tool will serve as a data entry tool to improve the quality of accident reporting, filling any knowledge gaps that new employees might have, and enhancing future analysis and safety data dissemination. By incorporating innovative Natural Language Processing techniques, this tool can help ensure more accurate and comprehensive incident reports, overcoming the limitations of manually curated narratives.

## Other Research

### Completed Research

1. **Developing Methodologies to Predict and Quantify the Benefits of IRISE Research:** Methodologies have been developed and applied to each of five IRISE research projects in order to quantify the benefits of the research results. The methodologies have been applied using and extrapolating data available from IRISE partners and other publicly available information on a national or state scale for highway infrastructure and user costs.

Website Link: <https://www.engineeringx.pitt.edu/IRISE/Research-Projects/Active-Projects/>

1. **Tactical Urbanism/Demonstration Projects Guide:** This project developed a Tactical Urbanism/Demonstration Projects Guide to help municipalities in Pennsylvania perform tactical urbanism/demonstration projects. A categorization of Tactical Urbanism projects based on several different aspects has been developed to help users of the Guide to better understand and describe projects’ contexts. The Guide includes Pennsylvania and nearby state case studies.

### Ongoing Research

1. **Developing and Applying Methodologies to Quantify the Benefits of IRISE Projects:** This project involves identifying up to five completed or ongoing IRISE research projects that offer implementable results for improving transportation infrastructure. The project will develop unique methodologies to quantify the benefits of implementing the research findings. The goal is to demonstrate how diverse types of research results can be measured and to evaluate their potential for broad-scale implementation, providing recommendations for each project analyzed.

## Pennsylvania Turnpike Mon-Fayette Expressway Test Bed

1. **Absorptive Sound Walls:** This project will develop a first-of-its-kind multifunctional sustainable noise wall. It involves developing a concrete metamaterial coated with titanium dioxide (TiO2) for application as a noise wall to reduce both NOx air pollution as well as noise around a highway. Phase 1 of the project will assess a number of potential designs for noise barrier metamaterial walls that could be readily translated into practice via modular construction. A second phase will involve fabricating large-scale prototypes of the identified optimal design. The goal is to produce a final design that can later be deployed for road demonstrations on a designated section of the Mon-Fayette Expressway.
2. **Digital Twin Technology:** Digital Twins facilitate quasi-real-time health assessment of complex infrastructure systems while enabling the use of advanced visualization techniques, including Augmented and Virtual Reality applications, for efficient access to and explicability of the data collected from field and remote sensors. This technology can be employed to perform accurate predictions of future system performance, while analyzing the current and predicted data in an efficient fashion. In this project, a Digital Twin of a selected portion of the Mon-Fayette Expressway will be developed. The Twin will be composed of a central model, which will obtain and process data from three main physical assets (pavements, bridges, and stormwater management) to ultimately enable a holistic approach for resilience assessment and risk-based maintenance of the Expressway.
3. **Electrified Roadway Strategic Plan:** This project will develop an “Electrified Roadways Strategic Plan” for the Pennsylvania Turnpike. The Plan will guide the Turnpike’s investment decisions and policies in the coming years as electric vehicle (EV) and dynamic wireless charting (DWC) technologies advance. The Plan will focus primarily on expanding in-road electric vehicle charging infrastructure for heavy-duty vehicles as the early adopters of the DWC technology, integration of distributed roadside renewable energy (solar and wind) generation, and leveraging opportunities to drive private investment in EV charging.
4. **Energy Harvesting:** This project will develop smart and multifunctional geosynthetics for pavements in the form of geogrids (potentially made from waste plastic as the main component). The designed sustainable geogrid would serve as a skin with sensing and energy harvesting functionalities, while providing optimal reinforcement for the road surface. The proposed solution harvests the energy from mechanical excitations caused by traffic and stores it using an energy harvesting kit for empowering roadside electronic devices. The potential of the proposed technologies for powering (embedded) wireless sensors and self-powered structural health monitoring in conjunction with the Digital Twin project will also be explored.