

UNIVERSITY OF PITTSBURGH | SWANSON SCHOOL OF ENGINEERING

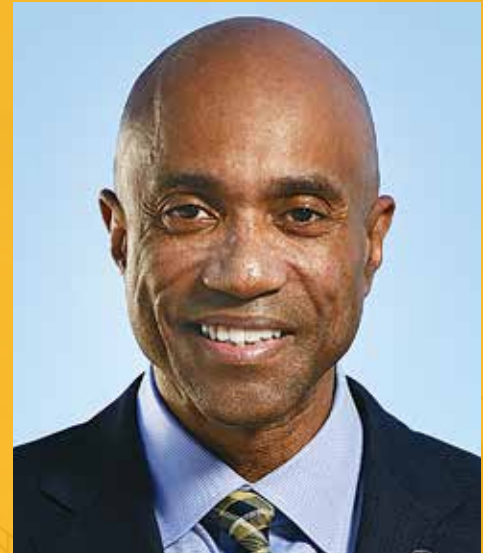
IRISE

The word 'IRISE' is rendered in large, bold, white letters with a slight drop shadow. The letters are semi-transparent, allowing the underlying textures of the background to be visible through them. The background is a collage of four distinct textures: a rusted metal surface in the top-left, a cracked concrete surface in the bottom-left, a blue-green patina on a metal surface in the top-right, and a yellowed, cracked asphalt surface in the bottom-right. The entire composition is set against a dark, semi-transparent background that tapers to a point at the top.

IRISE Consortium

Impactful Resilient Infrastructure
Science and Engineering

2019-20 ANNUAL REPORT



“In a financially constrained time, it’s imperative that new approaches to designing, building and maintaining transportation infrastructure be developed and implemented – ones focused on producing more durable and sustainable facilities, and ones able to cope with the increased risks posed by more severe weather events caused by global warming. I’m very happy that IRISE is addressing an issue of great importance to the people in the region and state. And I’m especially pleased that it is a public/private consortium. The ideas and solutions produced by a group like IRISE working together will be much better than by any single member working alone.”

James R. Martin II, PhD, M. ASCE
U.S. Steel Dean of Engineering

Greetings

I am pleased to report that the Impactful Resilient Infrastructure Science and Engineering (IRISE) research consortium in the Swanson School of Engineering at the University of Pittsburgh has had a very successful second year of operation. The members of the IRISE consortium understand how vital transportation is to our economy and well-being, and how critical it is to continue to find more cost effective ways of building and maintaining that infrastructure to increase its life expectancy.

We very much appreciate the participation of our consortium members: Allegheny County, Golden Triangle Construction, Michael Baker International, the Pennsylvania Department of Transportation and the Pennsylvania Turnpike. Their input has been invaluable in many ways – identifying relevant problems, guiding the research as it is being performed and providing opportunities for student learning experiences.

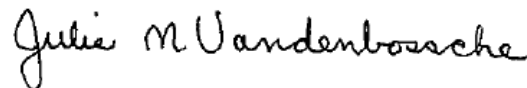
This second annual report provides information on our growing program. Several products are now available on our website (engineering.pitt.edu/irise) in areas such as steel bridge corrosion prevention and mitigation, concrete pavement design and concrete repairs. The results of these projects will not only help current professionals become more effective, but are also part of the knowledge base of emerging professionals as these advances are being integrated into the civil and environmental engineering curriculum.

We are particularly excited about the upcoming landslide seminar series we are planning together with the local geotechnical community as a follow-up to the very successful landslide workshop IRISE held this past summer. This an issue that has plagued Pennsylvania over the past few years, especially in this Southwest region of the state, and IRISE is excited to be working together in finding solutions.

But we can do more, and we're excited about ongoing projects in determining the feasibility of using microbes to promote self-healing in concrete, assessing bridge performance, using innovative techniques, determining the optimal timing for opening new concrete pavements to traffic, and educating practitioners about state-of-the-art practices in assessing and mitigating landslide areas.

We also look forward to getting our third year program started in late summer/early fall of 2020. Current topics being pursued include a landslide best practices document, investigating advanced technologies for improving worker safety at construction sites, exploring the problem of deterioration under pavement markings, and identifying new methods for transverse joint performance in pavements.

We are very proud of the history and tradition of civil and environmental engineering education and research at Pitt. In that spirit, we look forward to continuing to apply the University's expertise in producing practical, innovative solutions to transportation infrastructure problems. I invite your active participation and look forward to working with you to address the challenges we face.



Julie M. Vandebossche, PhD, PE

Director, IRISE



CENTER FOR IMPACTFUL RESILIENT
INFRASTRUCTURE SCIENCE & ENGINEERING





WHY IRISE



The nation's, state's and region's highway infrastructure has largely been built. Due to its age, the challenges of today are driven by the need for costly rehabilitation and renewal. The high costs and potential for rehabilitation and renewal projects to cause major disruptions makes it vital that these activities be performed in a more sustainable manner.

The Impactful Resilient Infrastructure Science and Engineering (IRISE) Consortium was established in the Civil and Environmental Engineering Department in the University of Pittsburgh's Swanson School of Engineering in 2018 to address these challenges.

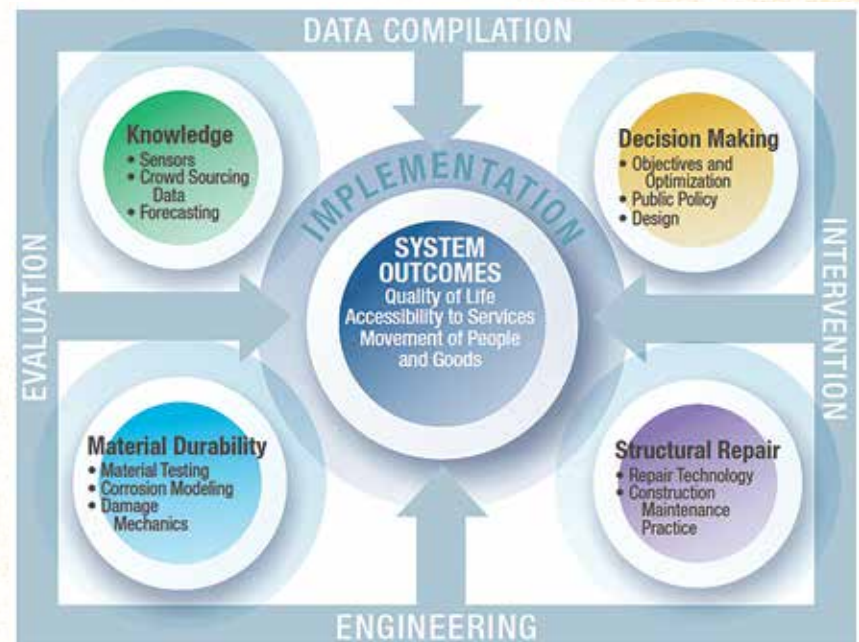
The five pivotal areas that are the focus of IRISE research are:

- Identifying and gathering information critical to the decision making process
- Accurately assessing the condition of the infrastructure system
- Analyzing user costs and benefits associated with deteriorating infrastructure and rehabilitation projects
- Identifying innovative construction materials and design and construction methods that produce a more viable infrastructure system
- Considering system outcomes when addressing weaknesses in individual infrastructure components

In conducting its research, IRISE is guided by two main principles:

- Innovative solutions to highway infrastructure problems can only be achieved through a collaborative program featuring public agencies that own and operate the infrastructure and the private companies that design and build it
- IRISE must provide implementable solutions that meet the needs of its members, especially in the short term, to continue to build interest and momentum

These principles were strongly reinforced at a July, 2019 Steering Committee strategic planning session.



THE PARTNER SHIP

The IRISE partnership includes three public and two private organizations. The Federal Highway Administration (FHWA) serves as an ex-officio member.

They have pledged a total of \$400,000 in annual funding for IRISE research. Administrative and management costs are covered by the University of Pittsburgh.

Participation in IRISE is enabling these organizations to:

- Identify and address priority research issues
- Participate in and shape research projects as they are being conducted

- Have immediate access to research results and products
- Interact with other IRISE members and University of Pittsburgh researchers and students

By virtue of their continuing participation and support, individuals representing these public and private partner organizations comprise a Steering Committee that has substantial influence on the research topics to be addressed and as a result, have a vested interest in implementing the research products.

At Michael Baker, we take pride in being leading-edge innovators and in engaging in helping to advance our communities. Our participation in IRISE strengthens our ability to achieve both of these goals.

H. Dan Cessna
Senior Vice President



Michael Baker
INTERNATIONAL

H. Daniel Cessna, Senior Vice President
Michael Baker International



George W. McAuley Jr., PE
*Executive Deputy Secretary,
Pennsylvania Department
of Transportation*

PennDOT continuously looks for opportunities to more effectively provide services. Throughout my career with PennDOT, and now nationally as Chair of AASHTO's Innovations Initiative, I've always been keenly interested in advancing research and innovation to deployment. We appreciate IRISE's focus on developing practical solutions and its partnering of the public, private and academic sectors in doing so.



Stephen G. Shanley, Director
Allegheny County Department of Public Works



U.S. Department
of Transportation
**Federal Highway
Administration**

Karyn Vandervoort, Program Management Analyst
Federal Highway Administration



Charles J. Niederriter, Chief Operating Officer
Golden Triangle Construction



Brian Wall, Research Division Manager
Pennsylvania Department of Transportation



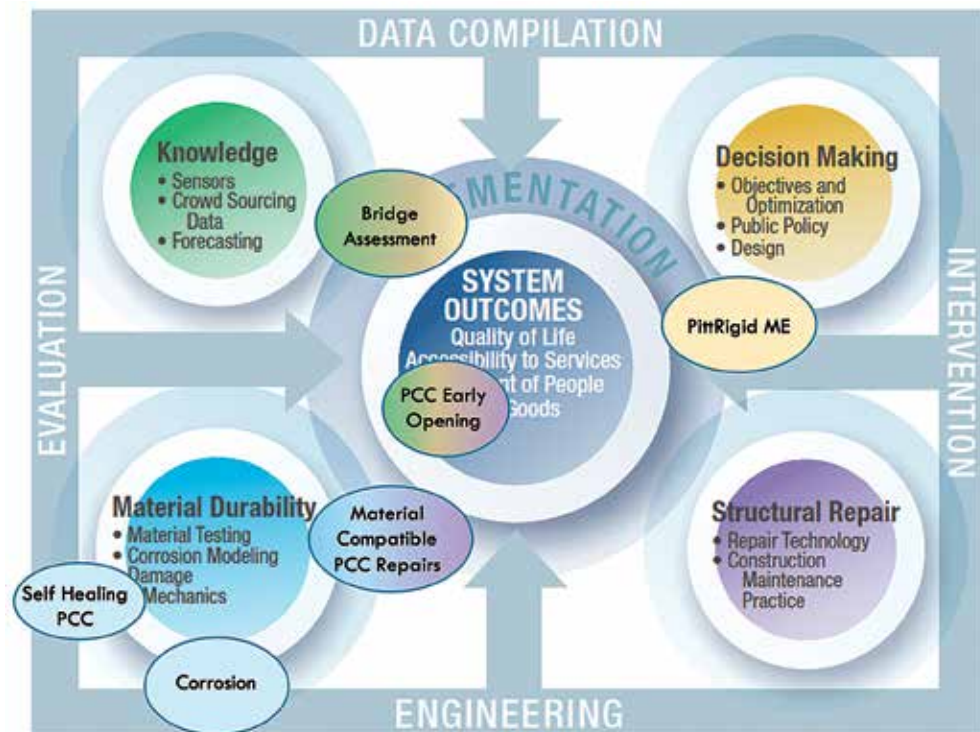
Michael Schultz, Strategic Planning &
Program Manager
Pennsylvania Turnpike Commission



ACTIVITIES

The following sections contain capsule descriptions of the individual projects that IRISE has completed, are ongoing, or that will be initiated. The graphic depicts how each of the recently completed and ongoing projects fit into the IRISE research framework. More information on each project can be found on the IRISE website: engineering.pitt.edu/Sub-Sites/Consortiums/IRISE/_Content/Achievements/Products/

- Completed Projects
- Ongoing Activities
- Student Involvement
- Planned Activities



Completed Projects

Steel Bridge Corrosion Prevention and Mitigation Strategies: Literature Review

Corrosion in steel bridges due to chloride attack as a result of exposure to marine environments or de-icing salts is a significant issue, which decreases structural integrity, increases maintenance requirements, and drastically increasing life-cycle costs. This report highlights important issues and identifies promising corrosion prevention, mitigation and repair methods. These include:

- Implementing duplex coating systems
- Identifying and evaluating novel approaches to prevent and mitigate crevice corrosion
- Developing artificial intelligence enabled corrosion monitoring methodologies
- Eliminating joints in existing structures using de-bonded link slabs
- Further developing in-situ repair strategies for corrosion damaged components

This initial step to identify promising methods of prevention and repairs of corrosion for bridges will help agencies in identifying viable options for extending the service life of bridges resulting in significant savings in future repair costs. Further research is needed to evaluate the longevity of specific methods.

Material Compatible Repairs (MCRs) for Concrete Pavements and Bridge Decks

Partial-depth repairs restore structural pavement integrity. However, they have not always achieved their expected life. An important consideration is the compatibility between the in-situ concrete and the repair material where the properties of the repair material can be significantly different than that of the existing concrete. In this project, various aggregate materials were obtained and the properties of different mixture designs assessed in the laboratory. A computational model was developed to evaluate the performance of repair mixtures over a range of vehicle and environmental loading conditions. The results show the selection of the coarse aggregate type plays a key role in achieving the desired stiffness and thermal compatibility. It was shown that environmental stresses that develop early in the life of the repair can be reduced by more than 60% through a reduction in drying shrinkage, although the long-term effects must still be investigated. Best practices for developing a performance engineering repair mixture (PERM) for placing an MCR were developed.

The benefit of using a PERM for concrete pavement and bridge deck repairs will extend the timeframe needed for future repairs. Implementation of these recommendations will help designers, contractors and agencies reduce future maintenance costs.



Photo courtesy of Allegheny County
Department of Public Works



Simplified Mechanistic-Empirical Design Tool for Pennsylvania Rigid Pavements (PittRigid ME)

To accelerate the implementation of the American Association of State and Highway Transportation Officials (AASHTO) Mechanistic-Empirical Pavement Design Guide (Pavement ME) in Pennsylvania, a simplified concrete pavement design method and a localized design software tool were developed. The new procedure, PittRigid ME, is based on the AASHTO Pavement ME design procedure, but reduces design input parameters to the most influential and relevant for Pennsylvania conditions. PittRigid ME predicts pavement performance (i.e. fatigue cracking and joint faulting) and determines the concrete slab thickness and dowel diameters for given performance criteria and reliability levels. It produces results that match the Pavement ME predicted performance at a fraction of the computational and design cost and reduces the potential for design errors.

Tailoring the AASHTO Pavement ME procedure to typical Pennsylvania conditions and making it easier to use results in reduced project design costs for transportation agencies. In addition, more widespread use of the Pavement ME procedure will save cost by producing thinner pavement designs that do not compromise performance than would otherwise have been produced by previous methods.



Exploring Approaches to Managing Landslide Risks Workshop Summary Report

With the proliferation of landslides impacting transportation systems in western Pennsylvania, IRISE conducted a forum to discuss current activities and develop consensus on needed research and development. 121 individuals representing over 40 organizations in the public, private and academic sectors participated. Presentations addressed:

- Historical Perspective and Identification
- Prediction, Remediation and Prioritization
- Managing Risks

The workshop concluded with a discussion of future needs by a panel consisting of leaders of western Pennsylvania government and academic institutions.

The workshop proved to be an excellent first step towards taking advantage of the knowledge and experience in the local engineering and geotechnical community. It provided a technology transfer opportunity to share experiences, discuss best practice approaches and help prioritize activities.



Ongoing Activities

The projects below will be ongoing throughout 2020.

Feasibility of Self-Healing Concrete Using Microbes

Reinforced concrete (RC) structures are susceptible to damage from long-term exposure to chloride-based compounds and/or repeated freeze/thaw cycles. An estimated \$16 billion per year is spent on the rehabilitation of RC structures using cementitious patching materials and/or chemical treatments. This study is evaluating the feasibility of increasing the durability, resiliency and sustainability of RC structures by using microbes to provide self-healing properties thereby preventing water and chloride ingress. The project is being conducted in partnership with the University's Mascaro Center for Sustainable Innovation.

The research holds promise for not only increasing the sustainability of RC structures, but also for mitigating adverse environmental impacts. It has far reaching applications for green building design and resilient and sustainable construction. Furthermore, the approaches and knowledge gained through this project can be applied to other disciplines, such as landslide mitigation.

Improving Bridge Assessment through the Integration of Conventional Visual Inspection, NDE, and SHM Data

A framework capable of leveraging emerging Structural Health Monitoring (SHM) and Non-Destructive Evaluation (NDE) techniques to provide improved performance assessment of bridges will be established. The proposed framework focuses on addressing the principal challenges associated with studying the service life of bridge structures. These are related to:

- Long-time periods (which require accelerated aging)
- Diverse outputs related to bridge condition (in terms of data collected through SHM, NDE, and visual inspection)

This is a collaborative effort with the Center for Advanced Infrastructure and Transportation (CAIT) at Rutgers University along with Wiss, Janney, Elstner (WJE) Inc. (industry partner). This research leverages access to the unique dataset generated by the Bridge Evaluation and Accelerated Structural Testing (BEAST) facility to identify the many potential synergies between SHM, NDE, and visual inspection for improving the current bridge condition assessment practice.



The framework being developed under this project aims to support bridge maintenance investment decisions that will reduce life-cycle costs. It will produce a comprehensive data-based approach that takes advantage of the strengths of various advanced data collection techniques.

Early Opening of Concrete Pavements to Traffic

Current empirical methods for determining traffic-opening criteria can be overly conservative causing unnecessary construction delays and user costs. These criteria require wait periods after concrete placement or achievement of certain levels of compressive and/or flexural strength of concrete. The proposed research will develop innovative mechanistic-based procedures for quantifying the risk of premature failure and long-term damage caused by traffic opening at various concrete strength levels. A methodology for the accurate monitoring of in-situ concrete early age development will be proposed. The research will develop a strategy for the optimal timing of the opening of new concrete pavements to traffic.



This research aims to reduce user costs associated with work zone delays, detour routing and delayed opening of new facilities, while not compromising the long term performance of newly placed concrete pavements.

Landslide Seminars

An issue discussed at length at the August 29, 2019 “Exploring Approaches to Managing Landslide Risks” workshop was what could be done to help build technical understanding among those working on landslide issues. This project entails a series of landslide seminars open to all professionals within the local engineering and geotechnical community. Each seminar will focus on a particular topic with invited presenters and discussion. Engaging student participation will also be a focus.

As a service to the community, these technology transfer seminars will enable those engaged in alleviating the landslide problem to share knowledge about occurrences, material properties, failure mechanisms, monitoring strategies, risk assessment strategies, best practices, and new innovations.





IRISE has provided me with opportunities to learn state-of-the-practice methods in the laboratory and classroom, and to supplement that knowledge through project site visits hosted by member organizations.

Charles Donnelly
Graduate Student

Student Involvement



Students benefited from IRISE activities in several ways. A number of students were financially supported and directly involved in IRISE activities. They, and many others, benefited from participating in IRISE activities and having information from IRISE projects included in their courses to help them bridge the gap between research and practical application.

Post-Doctoral Fellows

Naser Pourakbar Sharifi, PhD was a key staff member on the Materials Compatible Repairs project. He is a postdoctoral associate at Pitt whose research interests include novel techniques to increase the service life of concrete pavements and identifying best practices in concrete pavement design and maintenance in wet-freeze climates.



Lucio Salles de Salles, PhD was a key staff member on the PittRigid ME project. He is a postdoctoral associate at Pitt and a civil engineering professor at the Federal University of São Carlos in Brazil. His research interests include full scale and non-destructive pavement testing, finite element modeling and simulation, road markings, and overall pavement design and performance.

Supported Students

Several students were supported by IRISE projects during the past year, as indicated below:

- **Katelyn Kosar:** PhD student, Early Opening of Concrete Pavements
- **Haoran Li:** PhD student, PittRigid ME
- **Sarah Pitell:** PhD student, Microbes for Sustainable Construction
- **Zhe Sun:** PhD student, Material Compatible Repairs
- **Bin Wu:** Undergraduate student, Microbes for Sustainable Construction
- **Gloria Zhang:** PhD student, Improving Bridge Assessment
- **Yuzhao Zhou:** Masters student, PittRigid ME

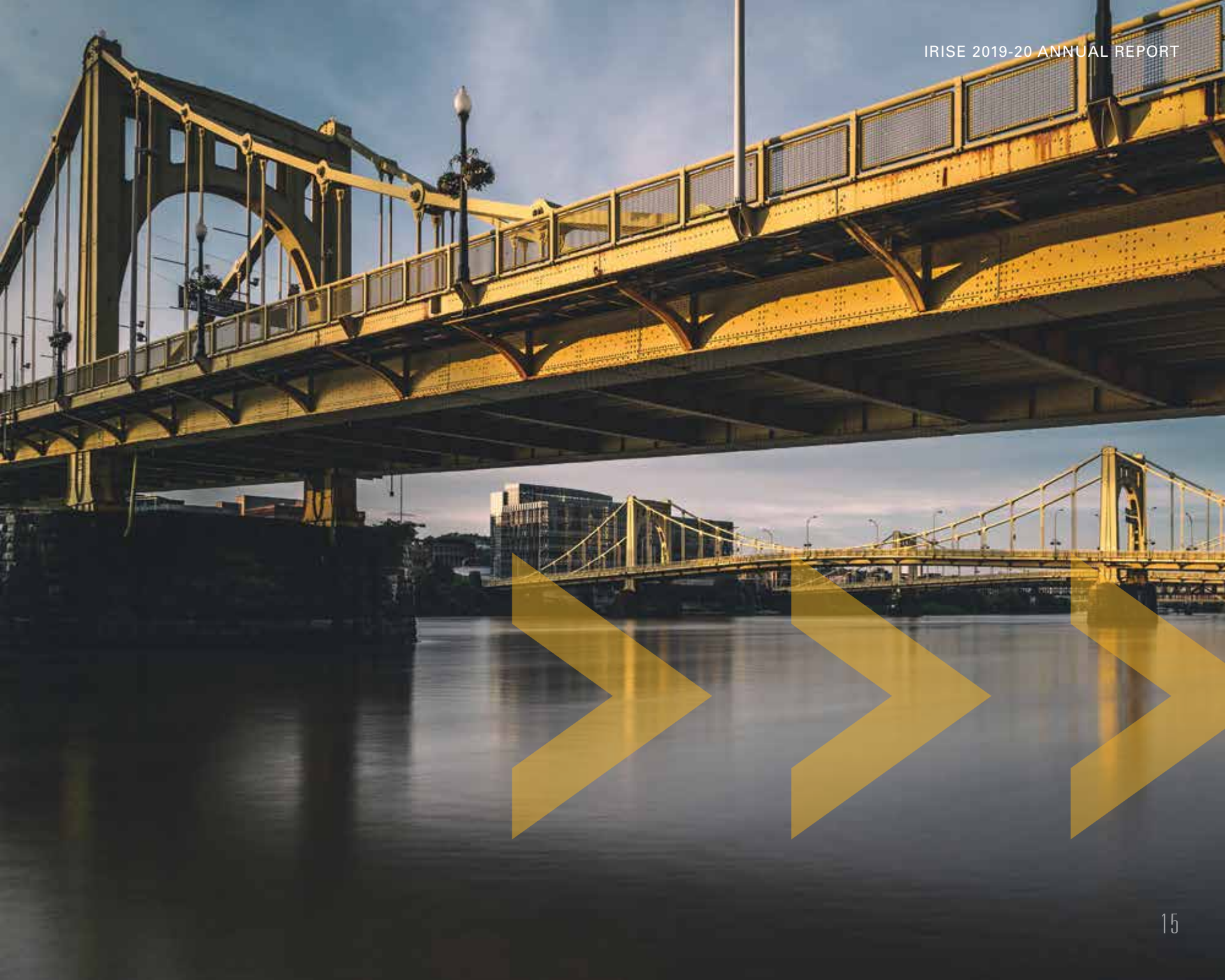
Presentations of their work were made at a variety of venues, including:

- Multiple students presented posters at the summer IRISE strategic planning session
- Multiple students also presented posters at the fall IRISE brainstorming session
- Sarah Pitell presented a poster on the Microbes for Sustainable Construction project at the 2019 Association of Environmental Engineering & Science Professors Conference
- Sarah Pitell had been accepted to present at a conference of the American Society for Microbiology and at a Gordon Research Conference before both were canceled due to the Covid-19 pandemic
- Naser Sharifi presented a poster on the Materials Compatible Repair project at the American Concrete Pavement Association's Pennsylvania Concrete Conference

Additionally, many other CEE Department graduate and undergraduate students benefited from involvement in IRISE activities including:

- Attendance at the Annual Meeting and brainstorming session
- Participation in the Exploring Approaches to Managing Landslide Risks Workshop including assistance with preparation of the summary report
- Assistance with laboratory work on the Materials Compatible Repair project
- Site visits included: the Pennsylvania Turnpike 43 jointed plain concrete pavement repair project, the Pennsylvania Turnpike Southern Beltway project, arranged with the cooperation of members Golden Triangle Construction and the Pennsylvania Turnpike, and several local landslide sites







Planned Activities

The process of planning next year's work program commenced in the fall of 2019 with a brainstorming session. Research ideas were gathered and short problem statements prepared and discussed with the IRISE Steering Committee and its technical representatives. The projects described below emerged from that process. If approved by the IRISE Steering Committee, work on these projects is expected to be initiated in the summer or early fall of 2020.

Landslide Best Practices Document

Discussion at 2019 IRISE events identified need for a best practices document that summarizes corrective actions that can be applied in situations with similar characteristics so that available funds can be most effectively used. This project will both identify and characterize how landslides can be mitigated under a range of initiating conditions and Identify improvements needed in current design and permitting procedures.



Safer Pavement Construction

Recent developments in robotics, artificial intelligence and materials science offer opportunities for development and implementation of automated, safe, and cost-effective QA/QC technologies and processes. Through an in-depth data and literature review, the most frequent accident types and the most promising and implementation-ready technologies will be identified. A technology transfer workshop with industry experts will be convened.



Concrete Curing Monitoring

A system for obtaining detailed information on concrete curing conditions (temporal temperature of concrete) as well as cylinder acceleration during transportation and handling will be developed and applied. The system is intended to help resolve disputes over low in-place concrete strength.



Evaluation of Pavement Surface Distresses Related to Pavement Markings

Transportation agencies have reported the presence of pavement distresses, such as cracking and raveling, under or along pavement markings. This project will investigate whether pavement markings are causing pavement surface deterioration and, if so, will develop approaches for mitigation this problem.



Systems Approach to Joint Design

The sustainability of jointed plain concrete pavements with minimal maintenance activities is dependent on joint performance. Joint performance depends on the interaction between the individual elements of the pavement structure, such as load transfer, drainage and joint reservoir/sealant design. A holistic approach to designing joints will be investigated to determine the effectiveness of current sealant types, reservoir designs and construction practices and to identify opportunities for improvement.

Material Compatible Repairs Evaluation

In order to validate and demonstrate the results of the IRISE completed research project “Material Compatible Repairs for Concrete Pavements and Bridge Decks” this project will conduct long-term field evaluations of partial depth repairs made using the report’s recommendations in comparison with those made using other methods in similar settings.



Quantifying the Benefits of IRISE Research

Methodologies will be developed and applied to ongoing and completed IRISE research results and products to predict and quantify the benefits that will accrue to IRISE members and other users.

FACULTY

Julie Vandenbossche, PhD, PE, serves as the IRISE Director. Dr. Vandenbossche is an Associate Professor with over 25-years of professional experience, including 18-years as a civil engineering professor at Pitt. She previously served as a senior engineer with the Minnesota DOT and as a loaned staff project manager with the Transportation Research Board. Dr. Vandenbossche has collaborated extensively with state agencies, industry, contractors and suppliers. These collaborations have been the foundation of her research to ensure that end products are relevant, innovative and implementable.

Gary Euler serves as the Associate IRISE Director, with day-to-day management responsibilities. Mr. Euler possesses 40-years of experience in both the public and private sectors, including time as a senior program manager in the U.S. Department of Transportation's Federal Highway Administration and as a business development manager for prominent engineering companies.

Amir Alavi, PhD serves as the Principal Investigator for the Improving Bridge Assessment project. Alavi's research interests include structural health monitoring, smart civil infrastructure systems, deployment of advanced sensors and engineering informatics. He is the director of the Pitt's Intelligent Structural Monitoring and Response Testing (iSMaRT) Lab.

Sarah Haig, PhD is the Principal Investigator for the Feasibility of Self-Healing Concrete Using Microbes project. She has broad microbial ecology expertise with experience isolating microbial degraders of emerging contaminants using both culture-based and molecular methods.

Anthony Iannacchione, PhD, PE, PG is leading IRISE landslide research and education activities. Prior to his appointment at Pitt, he worked for the U.S. Bureau of Mines and National Institute for Occupational Safety and Health. His research interests include assessing the surface impacts caused by longwall mining subsidence and designing underground facilities with minimal risk of environmental or workplace harm.

Lev Khazanovich, PhD served as the Principal Investigator for the PittRigid ME development and is now serving as the Principal Investigator for the Early Opening of Concrete Pavements to Traffic project. Over the past 25 years Khazanovich has been involved in various aspects of pavement research, design and evaluation, including performance prediction modeling, non-destructive testing and finite element modeling.

Mark Magalotti, PhD, PE serves in a senior advisory capacity. Magalotti previously served as the Coordinator of the Graduate Program for Transportation and as a Senior Lecturer in the graduate program for transportation engineering. He has conducted research in the area of multi-modal transportation planning.

Steve Sachs, PhD served as the Principal Investigator for the Materials Compatible Repairs project. His research interests include pavement design and analysis, finite element modeling, and experimental characterization of structures and materials.



Julie Vandebossche, PhD, PE



Gary Euler



Amir Alavi, PhD



Sarah Haig, PhD



Anthony Iannacchione, PhD



Lev Khazanovich, PhD



Mark Magalotti, PhD



Steve Sachs, PhD

The Future

IRISE's future will be guided by the following recommendations that emerged from the July, 2019, Steering Committee strategic planning session.

- Produce implementable results from smaller projects in the early years to help build interest and momentum
- Continue focus on applied research in the early years (1 – 3) then gradually increase the amount devoted to fundamental issues in the later years as the budget grows
- Undertake fundamental research with the idea that it will eventually lead to an applied research product
- Pursue high risk/reward topics, but not until funding levels have increased, and not to the detriment of addressing immediate infrastructure issues identified by members
- Pursue Federal sources of funding or higher risk/reward research
- Establish an IRISE mission to help ensure that investments are targeted and produce maximum return and to avoid duplication with research ongoing elsewhere



IRISE continues to pursue additional public and private sector members and external funding and partnership opportunities.

Our goal is to be the place where people go to get innovative, implementable solutions to their transportation infrastructure challenges.



IRISE

engineering.pitt.edu/irise



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