



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

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**Transportation Infrastructure Precast Innovation
Center (TRANS-IPIC)**

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Signature of Submitting Official:

Bassem Andrawes, TRANS-IPIC UTC Director

1. ACCOMPLISHMENTS

1.1. Major Goals

The Transportation Infrastructure Precast Innovation Center (TRANS-IPIC) is a Tier 1 University Transportation Center (UTC) that focuses on improving the durability and extending the life of transportation infrastructure by advancing the technologies used in precast concrete (PC) construction and maintenance. The consortium is composed of the following five universities:

- University of Illinois at Urbana-Champaign (UIUC) – Lead Institution
- Purdue University (PU)
- University at Buffalo (UB)
- Louisiana State University (LSU)
- University of Texas, San Antonio (UTSA)

TRANS-IPIC's mission is to leverage research innovation and strong industry support to guide and provide leadership in the transportation domain's highly overlooked area of precast concrete technology. TRANS-IPIC's innovative research on PC-related technologies aims to develop short-term solutions for current infrastructure problems and revolutionize the development and performance of future infrastructure of various transportation modes, providing gains in durability, safety, and economy. The primary goals of TRANS-IPIC are:

- 1) Develop durable, cost-effective advanced materials (concrete and reinforcement) for precast components.
- 2) Develop a new design framework for infrastructure PC elements based on innovative computational mechanics, topology optimization, and efficient manufacturing and accelerated construction processes.
- 3) Advance the field of building information modeling (BIM), automated manufacturing, repair, and inspection of precast infrastructure using new technologies like drones, satellite imaging, and 3D printing of forms and concrete.
- 4) Incorporate novel "built-in" quality control, self-assessment, and repair mechanisms in PC components.
- 5) Establish comprehensive economic plans for operating, managing, and processing off-site PC manufacturing, shipping, and installation.

1.2. Activities During This Period

During this period, the following activities have been completed:

1. **Hosted the 2nd Annual In-Person TRANS-IPIC UTC Workshop:** TRANS-IPIC partnered with the Precast/Prestressed Concrete Institute of Illinois & Wisconsin (PCI-IW) to organize our 2025 in person UTC Workshop. During the period of this report, there was extensive planning for this event. This two-day Workshop was held on Tuesday, 04/22/2025, and Wednesday, 04/23/2025 at the Big Ten Office and Conference Center (Rosemont, IL). Over the two days of this event, faculty members from (18x) research teams (and their students) from the University of Illinois Urbana-Champaign, Purdue University, Louisiana State University, University at Buffalo, and University of Texas at San Antonio attended to present research talks and poster sessions. Additionally, TRANS-IPIC worked extensively with the following external companies: HDR, Architectural Polymers, Sumiden Wire, Walsh Construction, Holcim, the Illinois Tollway, WSP, Chryso-Saint Gobain, and Nawkaw, to host presenters from each on the latest industry projects and technologies impacting precast concrete. Additionally, representatives from both the Indiana Department of Transportation and Illinois Department of Transportation attended to meet with researchers and provide insight, including one DOT presentation related to challenges impacting precast concrete. Two precast manufacturers participated in this event, the first providing a multi-hour onsite plant tour of a precast facility (Dukane Precast) at their Auora, IL, facility. This plant tour was provided free to all attendees. The second, County Prestress and Precast, LLC, presented to attendees on the Illinois Tollway I-294 Mile Long Bridge Construction Methods. Of the (18x) research teams from our consortium universities in attendance, nine provided the latest updates for TRANS-IPIC funded research projects, for projects in the second (and final) year of funding. The remaining research teams presented posters during multiple designated poster sessions. There were a combined total of (14x) posters, allowing students to interface directly, in a 1-on-1

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capacity, with industry and DOT attendees. To aid the ability of University of Illinois students to attend the Workshop, in a safe and convenient manner, a shuttle was provided from the University of Illinois Urbana-Champaign campus directly to the Workshop, from the Workshop to the Plant Tour, and finally from the Plant Tour returning directly to the University of Illinois Urbana-Champaign campus. We are pleased with the 2025 TRANS-IPIC UTC Workshop turnout. On Day 1 of the event, we estimate approx. 90 individuals in attendance (Day 1 included the shuttle from the University of Illinois Urbana-Champaign campus to and from the event for interested students, 6 presentations, and plant tour). On Day 2 of the event, we estimate approx. 70 individuals in attendance (Day 2 included the majority of the presentations, twelve in total, and multiple poster sessions).

TRANS-IPIC UTC		Agenda		TRANS-IPIC UTC	
Tues, April 22		Weds, April 23		April 23, cont.	
8:30-8:55 a.m.	Breakfast/Networking	8:00-9:00 a.m.	Breakfast/Poster Viewing/ Faculty Meeting	12:15-1:00	Lunch/Poster Viewing
8:55-9:00	Welcome and Summary Remarks Bassem Andrawes, TRANS-IPIC Director	9:00-9:30	3D Printed Advanced Concrete Materials to Mitigate Prestressed Concrete Girder End Cracking Pi Raw Ranade, University at Buffalo Presenter: Pranay Singh	1:00-1:30	Cooler Sidewalks with PCM- Enhanced Precast Concrete Pi Samer Dessouky, University of Texas at San Antonio Presenter: Islam Radwan
9:00-9:30	3D Printing for Superior Strength, Toughness, and Impact Resistance applies to roadside barriers Pi and Presenter: Pablo Zavattieri, Purdue University	9:30-10:00	Illinois Tollway I-294 Mile Long Bridge Construction Methods Emily Dougherty & Nick Faul, Walsh Construction & Gary Counney & Preston Moore, County Prestress and Precast, LLC	1:30-2:00	Current issues with Precast Concrete Pavement, Structural Elements, and their uses in the future Pi Tommy Nantung, Indiana Department of Transportation
9:30-10:00	Construction of Precast Segmental Arches in Downtown Miami Presenters: Michael Lamont & Alvaro Aranguren, HDR	10:00-10:30	Innovative External Prestressing Technique using Shape Memory Alloy-Coupled Prestressing Plates Pi Bassem Andrawes, University of Illinois Urbana-Champaign Presenter: Dachina Gunasekaran	2:00-2:30	Optimal Procurement Schedules of Raw Materials for a Precast Concrete Manufacturing System Pi and Presenter: Bhaba Sarker, Louisiana State University Presenter: Islam Radwan
10:00-10:30	Optimizing the Planning of Precast Concrete Bridge Construction Methods to Maximize Durability, Safety, and Sustainability Pi Khaled El-Rayes, University of Illinois Urbana-Champaign Presenter: Hadi Healy	10:30-10:45	Morning Break/Poster Viewing	2:30-2:45	Afternoon Break/Poster Viewing
10:30-10:45	Break/Poster Viewing	10:45-11:15	The future of Cement manufacturing Presenter: Rusty Owings, Holcim	2:45-3:15	Innovative Precast through Advanced Admixtures Presenter: Daniel Drenth, Chryso- Saint Gobain
10:45-11:15	Architectural Formlins for Highway Applications Presenter: Carey Cornwell, Architectural Polymers	11:15-11:45	CO2 Curing Process Optimization for Strength and Microstructure Enhancement of Cementitious Composites Modified with Recovered Carbon Black Nanoparticles Pi Mirian Velay-Lizancos, Purdue University Presenter: Anyia Edwards	3:15-3:45	Data-Driven Smart Composite Reinforcement for Precast Concrete Pi and Presenter: Chengcheng Tao, Purdue University Presenter: Junyi Duan
11:15-11:45	An Enhanced and Implementable Machine Learning-Based Evaluation Tool for Prestressed Concrete Bridges Pi Pinar Okumus, University at Buffalo Presenter: Mohamed Hassan Lasheen	11:45-12:15 p.m.	Illinois Tollway Precast Concrete Innovation Presenters: Dan Cancarci, Dr. Ahmad Hamad, Joe Pitlik, Illinois Tollway & WSP	3:45-4:15	Architectural Finishes and Color Solutions for Concrete Presenter: Dave Ellis, Nawkaw
11:45-12:15 p.m.	Advanced Prestressing Steels: Corrosion Resistant and Smart Materials Presenters: Jon Cornelius & Matt Speedy, Sumiden Wire			4:15-4:20	Closing Remarks Bassem Andrawes, TRANS-IPIC Director
12:15-1:00	Lunch/Poster Viewing			4:20-5:00	Networking/Poster Viewing/ Snacks
1:00-5:00	Plant Tour - Dukane Precast				

Fig 1. Agenda for the 2025 TRANS-IPIC UTC Workshop held Tuesday, 04/22/2025, and Wednesday, 04/23/2025 at the Big Ten Office and Conference Center (Rosemont, IL).

- 2. Initial Planning for the 3rd Annual In-Person TRANS-IPIC UTC Workshop:** Following the conclusion of the 2025 TRANS-IPIC UTC Workshop, the TRANS-IPIC Management Team began planning the 2026 UTC Workshop. Due to how quickly event spaces book in and around Chicago, planning for each year's event must take place as early as possible. After looking into multiple event spaces, the TRANS-IPIC management team has settled on holding our 2026 UTC Workshop on Tuesday, 04/14/2026, and Wednesday, 04/15/2026, also at the Big Ten Office and Conference Center (Rosemont, IL). This event space was selected due to its proximity to the O'Hare Airport, which aids the ability for out of state consortium members, industry members, and DOT participants to attend. For the 2026 UTC Workshop, TRANS-IPIC has multiple state DOT members, external to Illinois, planning to attend and present on real-world projects (Texas, Tennessee, and Nebraska). Illinois DOT representation is also expected to attend. For the 2026 UTC Workshop, TRANS-IPIC will be updating the event plan to include published proceedings following the event, which include manuscripts from all research teams, and each manuscript will be give an individual DOI and the entire symposium Proceedings will be published on the Social Science Research Network (SSRN). The TRANS-IPIC Management team has requested approval to hold this event in 2026.

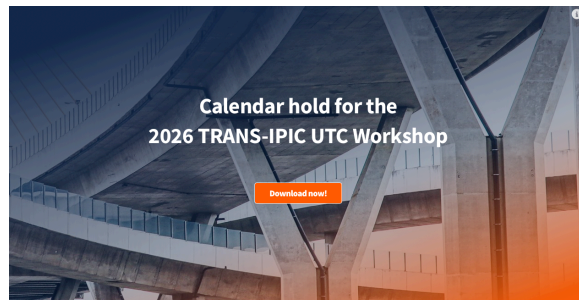


Fig 2. Dedicated webpage and event information, including a calendar hold, are currently available on the TRANS-IPIC website for the 2026 TRANS-IPIC UTC Workshop to be held Tuesday, 04/14/2026, and Wednesday, 04/15/2026 at the Big Ten Office and Conference Center (Rosemont, IL).

- 3. Initial Planning for the Symposium on Shape Memory Alloys (SMAs) in Infrastructure:** The TRANS-IPIC management Team has begun extensive planning for a new symposium event dedicated to Shape Memory Alloys in Infrastructure. This symposium will provide a forum to discuss the state-of-the-art research, emerging applications, and future directions of SMAs in structural, infrastructure, and transportation systems. The event aims to connect researchers, engineers, and industry professionals to exchange knowledge on how SMA's unique thermomechanical properties, including superelasticity and shape memory effect, can be utilized to improve the safety, resilience, durability, and adaptability of civil infrastructure.

This 2026 SMA symposium is a 2-day event to be held at the Big Ten Office and Conference Center in Rosemont, IL. The exact date of the event is expected to be September 17th and 18th, 2026. The TRANS-IPIC management team is targeting 50 manuscript submissions and presentations for this symposium, with the proceedings published on the Social Science Research Network (SSRN) following the event. Approx. 60 attendees are anticipated. A symposium chair, and three organizing committee members have agreed to aid with planning the event, and (26x) faculty members from seven countries have agreed to serve on the Scientific Committee to review manuscripts.

Topics expected to be covered on submitted manuscripts and presented in person at the symposium are Material Behavior & Characterization (Thermo-mechanical properties, fatigue, and constitutive modeling of SMAs), Seismic Applications (SMA-based dampers, braces, and self-centering connections for earthquake resilience), Prestressing & Strengthening (SMA bars, tendons, and wires for prestressing, retrofitting, and crack control in concrete structures), Structural Applications (Use of SMA in bridges and other types of structures), Infrastructure Applications (SMA for pipelines, pavements, foundations, transportation networks, and resilient lifeline systems), Smart & Adaptive Systems (Integration of SMA in hybrid designs, adaptive structures, and smart infrastructure), Durability & Lifecycle Performance (Durability, corrosion resistance, and long-term reliability), Numerical Modeling & Simulation (Finite element modeling, design methods, and predictive analysis of SMA-based systems), and Implementation & Industry Adoption (Case studies, challenges in field application, cost considerations, and progress toward design codes).

The Transportation Infrastructure Precast Innovation Center (TRANS-IPIC) will not pay for international travel of attendees or speakers. The TRANS-IPIC Management team has requested approval to hold this event in 2026.

- 4. Highschool Outreach at University at Buffalo:** The research team working on the funded project 'Evaluating Prestressed Concrete Beams with Cracks using Machine Learning – Phase II' presented on the evaluation of cracked bridges using machine learning on August 7, 2025, to a number of high school students as part of the National Summer Transportation Institute that took place at the University at Buffalo campus in Buffalo, NY. The Institute aims to encourage K-12 students to consider transportation related careers. A photograph from the event is shown below.

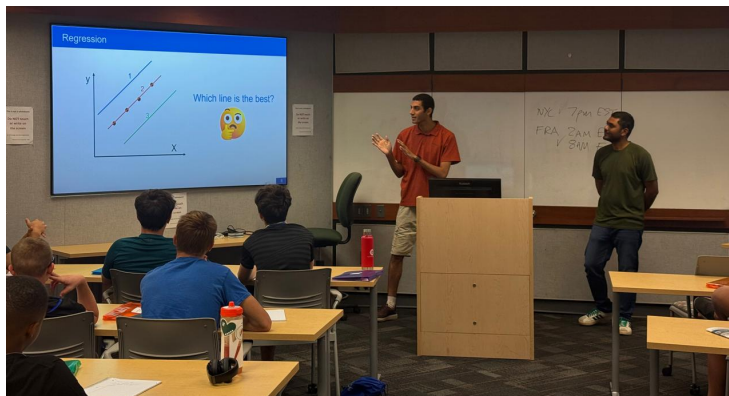


Fig 3. High school students attending the National Summer Transportation Institute that took place at the University at Buffalo campus in Buffalo, NY and learning about projects and tools developed as part of TRANS-IPIC projects.

- 5. TRANS-IPIC hosted 24 high school students during the Building with Memory session of The Grainger College of Engineering and WYSE Worldwide Youth in Science and Engineering program City Designers and Builders Camp:** Students who participated ranged from those with a casual interest in the field of engineering to some already with goals of working in transportation infrastructure. In the first part of the session, members of the Shape Memory and Structures research group and graduate students Alexander Chen, Siyoung Park, Ernesto Pérez-Claros, Kazi Ishaq Mushfiq, and Osama Ibrahim as well as mechanical science and engineering professor Ann Sychterz presented information and demonstrations of equipment used by TRANS-IPIC researchers. In the second part of the session, students got to tour Newmark Crane Bay, seeing test setups for large-scale precast bridge girders and slabs.

Quotes from students attending this summer camp:

“I am very interested in civil engineering – specifically transportation engineering – and thought that this camp would be a great way to learn more about the major.” -ManYi, Grade 11

“I want to be an influence to communities while using my love for math and physics, and wanted to learn what it takes to do so as a civil engineer.” -Joshua, Grade 11

“[Precast concrete infrastructure] seems interesting, applicable, and helpful for society.” -Matteo, Grade 12

“The most interesting thing I learned today was the possible future applications of memory retaining materials in structure and what it could mean for the life of things like bridges or buildings” -Sabelle, grade 12

“I liked the demo with the metal coils that were heated and went back to their original shape.” -Natalie, grade 11

“I thought the SMA's were very interesting. They don't deform easily and can't 'rebound' to their original shape.”-Nina, grade 11





Fig 4. Event photos from the TRANS-IPIC 'Building with Memory' summer camp working with the Grainger College of Engineering and WYSE.

- 6. Hosting Research Highlights Webinars:** Research Highlights Webinars to promote and disseminate the research conducted by TRANS-IPIC researchers have been held in 2025 on February 19th, March 28th, May 21st, July 25th, August 22nd, September 26th, and October 24th. These Research Highlights Webinars are presented directly by faculty members, PIs or Co-PIs for each project, and accompanied by their students, to highlight the interesting research findings and discuss how to achieve the goals of the center. Each webinar includes between two to three presentations related to the UTC projects. Each webinar offers 1.0 Professional Development Hour (PDH) to attendees, and all are uploaded to TRANS-IPIC's YouTube channel for later viewing (and PDH). An ongoing and up to date playlist of all TRANS-IPIC Research Highlights Webinars can be found at the YouTube channel, <https://www.youtube.com/@TRANS-IPIC>.
- 7. Quarterly Progress Reports:** Utilizing an online system developed for the TRANS-IPIC researchers to share their projects' quarterly progress reports (QPRs), TRANS-IPIC has collected Quarterly Progress Reports through. These reports are reviewed by the center's leadership team to ensure that the funded projects are on the right track. After reviewing the reports, the TRANS-IPIC management team provides the project Principal Investigators (PIs) with feedback about their progress. A copy of the QPRs is posted on

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the TRANS-IPIC's website (<https://trans-ipic.illinois.edu/research>).

- 8. Request for Proposals for Year 3 Projects:** Starting in June of 2025, the TRANS-IPIC management team began our Call for Proposals process in order to select Year 3 projects for funding. TRANS-IPIC received a total of 32 research project proposals submitted to this open call. (8x) Proposals were from the University of Illinois Urbana-Champaign, (6x) Proposals from Louisiana State University, (4x) Proposals from Purdue University, (6x) Proposals from the University at Buffalo, and (8x) proposals from the University of Texas San Antonio. TRANS-IPIC utilized a total of (24x) external reviewer, selected from members of the TRANS-IPIC External Advisory Board and Industry Partnership Committee, and additional members of companies represented by committees. These external reviewers, from both DOTs and various industry partners, assessed and rated proposals based on criteria provided the TRANS-IPIC Management Team. Proposal Reviewers were from the following organizations: Illinois Department of Transportation, Indiana Department of Transportation, Louisiana Department of Transportation, Texas Department of Transportation, American Segmental Bridge Institute – ASBI, Precast/Prestressed Concrete Institute (PCI), Precast/Prestressed Concrete Institute of Illinois/Wisconsin (PCI-IW), Utility Concrete Products (UCP), HNTB, HDR, Wiss/Jannay/Elstner Associates – WJE, Research Civil Engineer with the US Army Corps of Engineers, Parsons Corporations, EXP, AtkinsRealis, and Coastline Composites.

This Call for Proposal process included both Research Projects previously funded by TRANS-IPIC in Year 2, which were seeking additional funding to continue their research in Year 3, and proposals for entirely new research projects. Because of this, proposals are separated into those seeking extensions and new research ideas seeking funding. This allowed the review process to be tailored to assess whether 'new' research ideas rated based on innovation, durability, potential for implementation, research quality, and workforce development. Additionally, projects seeking additional funding to continue research were assessed based on the finding and results accomplished during Year 2, the research plan and quality for Year 3, and plans for workforce development. Additionally, to be compliant with the 2025 Executive Orders and Secretarial Memoranda, projects were pre-reviewed to confirm none relate to climate change, environment, greenhouse gas emissions, sustainability, or DEI.

- 9. Final Project Reports and Year 2 Reports:** TRANS-IPIC collected Final Reports for Year 2 Exploratory Projects and (1x) research project from Year 1 that previously had requested an NCE. Final Reports were then reviewed by the center's leadership team to ensure all projects met their research goals and can be closed out. Additionally, Year 2 Research Project ending in 2025 will have their Final Reports collected on ~12/01/2025, in order to review before year end. (2x) research projects that were initially funded in Year 2 and will continue this same research in year 3 will have the year-end reports (for the continuation projects) reviewed to confirm each is at an acceptable point to continue funding. A copy of all Final Reports will be posted on the TRANS-IPIC's website (<https://trans-ipic.illinois.edu/research>) once completed and reviewed by the TRANS-IPIC Management Team.
- 10.** TRANS-IPIC would like to highlight Exploratory and Research Projects completed in Year 2 that illustrate the groundbreaking research into precast concrete in transportation infrastructure:

Project Highlight 1: Combining Specific Heat of Concrete and Actuator Placement Optimization for Self-Powered Ice-Melting Precast Concrete Bridge Panels led by Dr. Ann Sychterz at UIUC.

This research successfully demonstrated the feasibility of self-powered deicing system for precast concrete bridge panels using piezoelectric vibration energy harvesting technologies. The key findings include: (1) The various modifications to the concrete did yield a change to the thermal transfer properties. The formulation using both the silica fume and the steel fibers had the highest rate of heat dissipation indicating the lowest specific heat. This also suggests that multiple strategies can be employed simultaneously with additive effects. (2) Energy Harvesting Performance: A three-sensor PVEH system achieved resonant frequencies of 21 Hz and 33 Hz, generating peak-to-peak voltages of 31.62 mV and 12.29 mV, respectively. Under simulated bridge vibration conditions, the system harvested 0.077 J/day, or approximately 28 J/year. Adjustable tip masses and magnetic spacing effectively tuned the frequency response, broadening the operational bandwidth to match low-frequency bridge vibrations. (3) Heat Generation Effectiveness: The Nichrome wire embedded three inches below the concrete surface increased the slab temperature from 24°C to 45°C within four hours. This confirms the system's capability

to deliver sufficient heat for ice prevention, even with limited power input. (4) System Integration: The integration of AC-to-DC conversion circuitry, energy storage, and automated switching between charging and heating modes created a functional prototype that operates independently of external power sources.

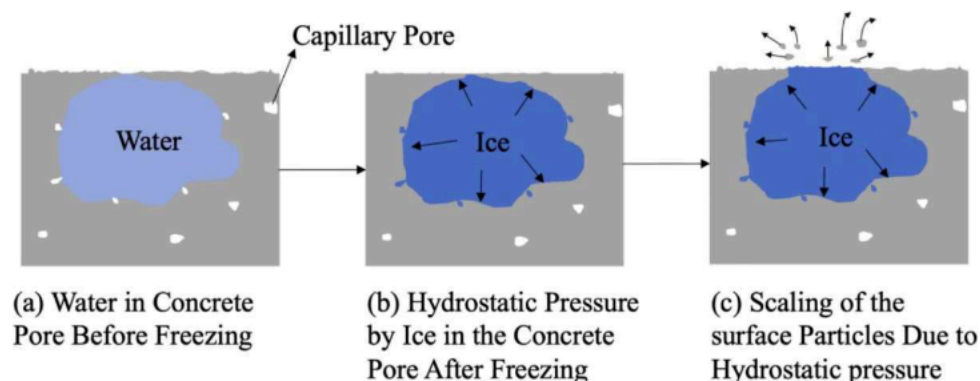


Fig 5. Mechanism of scaling due to hydrostatic pressure. (a) water in the concrete pore before freezing; (b) hydrostatic pressure by ice in the concrete pores after freezing where the capillary pores leave space to the increased ice volume (c) scaling of the surface particle due to hydrostatic pressure.

Project Highlight 2: AI-based Lift Path Planning for Robotic Installation of Precast Bridge Components led by Dr. Jiannan Cai at UTSA.

This exploratory project successfully developed and evaluated an AI-based framework for 3D crane lift path planning for the robotic installation of precast bridge components within a physics-based dynamic simulation environment. The research proved the feasibility and benefits of applying advanced AI, specifically DRL, to automate complex crane operations in transportation infrastructure construction. A highly realistic and functional physics-based simulation environment was successfully developed in MuJoCo, accurately replicating crane dynamics and precast component interactions at a 1:1 scale. This environment proved to be a reliable platform for training and evaluating the AI agent, demonstrating its capability to model complex construction scenarios. The developed DRL agent, utilizing the PPO algorithm and a novel two-phase training approach, effectively learned to autonomously control the mobile crane for precast concrete placement. This model achieved a zero-collision count and a 100% success rate across

The primary impact of this research is its potential to revolutionize the installation of precast bridge components. Currently, this process is labor-intensive, time-consuming due to repetitive re-lifting, and susceptible to human error, all exacerbated by a significant labor shortage in the construction industry. The developed AI-based system demonstrates the feasibility of automating these complex operations, offering a viable solution to these challenges.

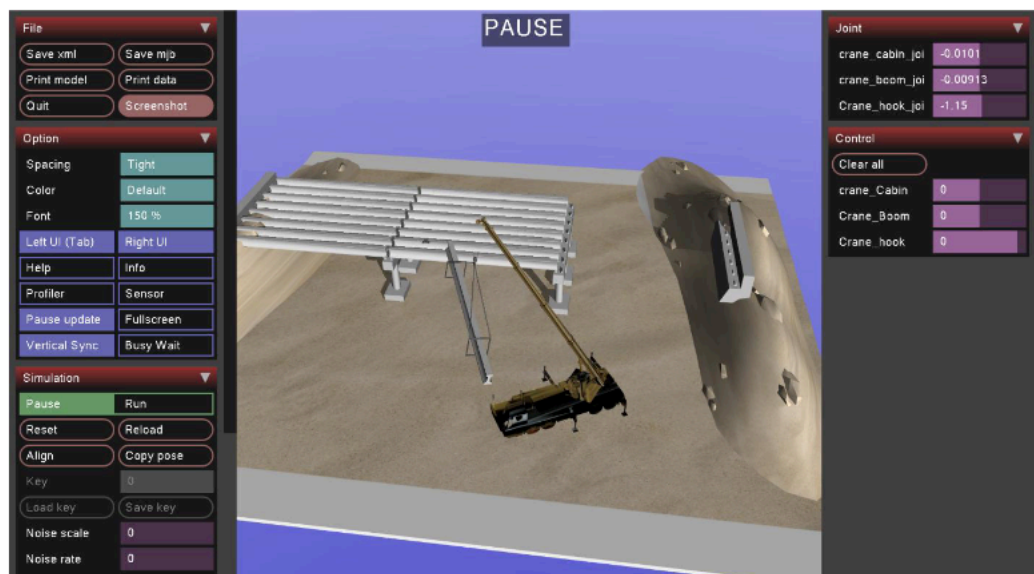
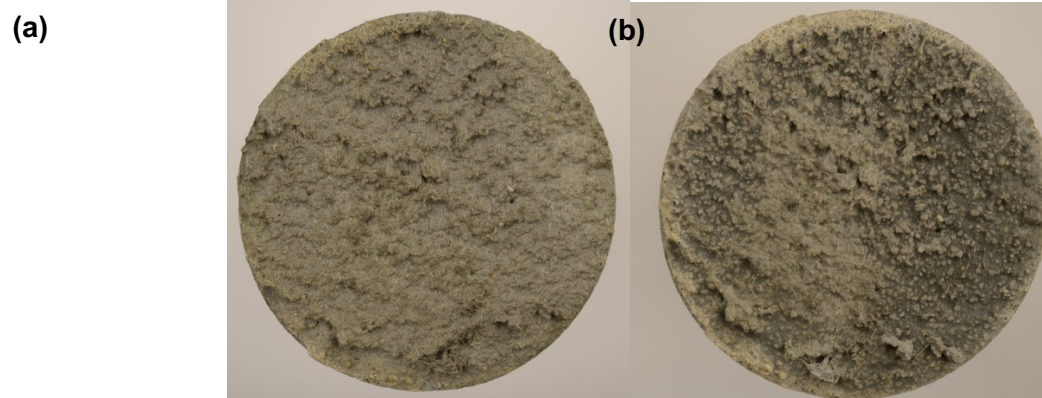


Fig 6. The Initial Simulation Environment in MuJoCo.

Project Highlight 3: Exploring Fungal-Induced Carbonate Precipitation (FICP) for Healing Concrete Cracks led by Dr. Hai Lin at LSU.

This study demonstrated the feasibility of using bio-based methods, specifically fungal strains, to enhance crack healing and durability of cementitious materials. Among the tested strains, *Neurospora crassa* (NC) exhibited the best performance in promoting early hardening, increasing compressive strength, and reducing water absorption. The incorporation of hydrophilic cellulose fibers facilitated more uniform distribution of biological agents and enhanced water ingress during treatment, which contributed to improved healing outcomes. Mechanical (compressive strength), acoustic (P- and S-wave), and permeability (water absorption) tests collectively confirmed the improvement in internal matrix continuity and healing efficiency post-treatment. One notable and unexpected observation in this study was the increase in compressive strength in mortar specimens treated with fungal cultures, particularly *Neurospora crassa* and *Aspergillus niger*.

This study highlights the potential of incorporating fungal-induced biomineralization into cement-based materials to improve their self-healing capability and durability. In transportation infrastructure—such as bridges, pavements, tunnel linings, and retaining structures—cracking remains a persistent challenge, often resulting in high maintenance costs and reduced service life. The experimental results demonstrate that mortar specimens treated with fungal cultures, particularly *Neurospora crassa*, in combination with hydrophilic fibers, exhibited not only enhanced healing performance but also improved mechanical properties. These findings suggest the feasibility of using fungal agents as a biological additive to promote long-term integrity and passive self-repair of concrete structures.



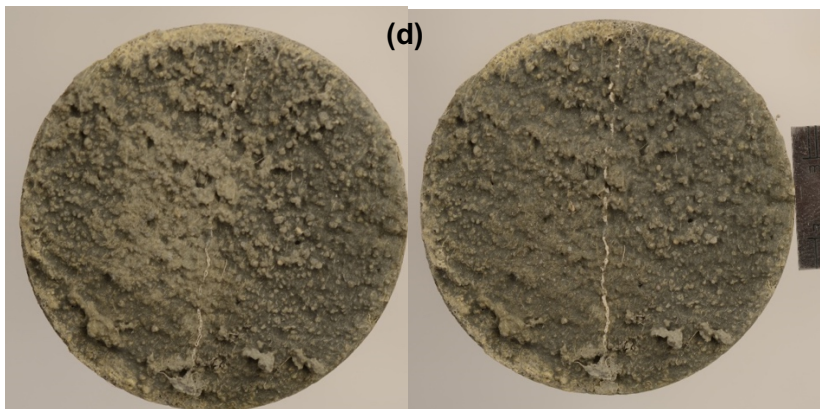


Fig 7. From this study, a time-lapse images of the bottom surface of specimen *Aspergillus niger* with fiber showing crack healing.

Project Highlight 4: IoT-Driven Digital Twin Framework for the Design and Fabrication of Precast Elements led by Dr. Ibukun Awolusi at UTSA.

The advent of advanced technologies such as Internet of Things (IoT) and Digital Twin (DT) has significantly reshaped numerous industries, including construction, by facilitating real-time data monitoring and more informed decision-making. Precast concrete components are widely utilized in construction for their efficiency and high quality. Integrating IoT and DT technologies into their production and use holds great potential to enhance their design, manufacturing, and lifecycle management. Through real-time monitoring, companies can reduce defects and maintain higher quality standards by quickly adjusting operations to align with design specifications. In this research, a systematic review was conducted to characterize the potential applications of IoT and DT in the design and fabrication of precast elements, and the findings were used to develop an IoT-enabled DT framework that can be deployed to enhance the efficiency of the design and fabrication of precast elements. This research examined the design process and requirements for the fabrication of precast concrete elements and the impact of integrating IoT and DT technologies for real-time monitoring, feedback, optimization, and control of the design, fabrication, and post-fabrication lifecycle of precast elements. The framework developed in this study should be implemented in a real-world recast design and fabrication process to validate and further improve it.

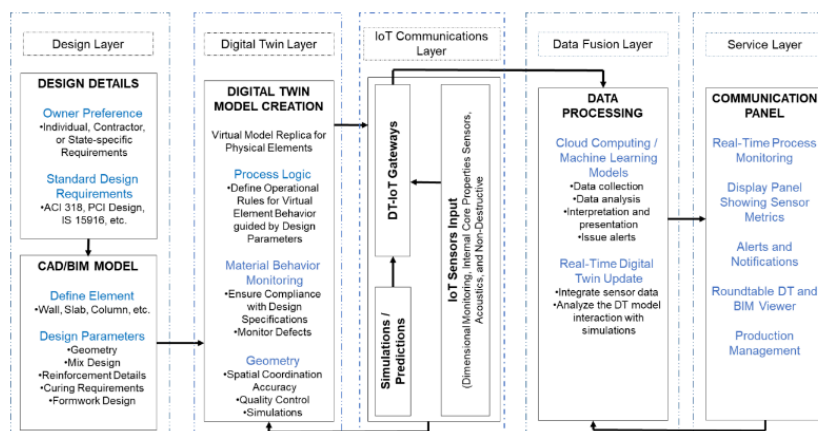


Fig 8. Conceptual IoT-driven DT framework for precast concrete design and fabrication.

Dissemination

- 1) Conferences and Meetings:** The outcomes from the TRANS-IPIC UTC projects were highlighted at multiple events that are heavily attended by transportation professionals. As mentioned earlier, targeting attendance of transportation professionals is an ongoing center goal for the yearly TRANS-IPIC Workshop (held each April). TRANS-IPIC researchers also heavily focus on having papers published at the TRB

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annual meeting. In preparation for the 105th TRB Annual Meeting on January 11–15, 2026, TRANS-IPIC has (8x) papers already accepted for presentation. A sample of these papers are below for reference:

(8x) selected of TRB Accepted papers acknowledging TRANS-IPIC:

- Experimental And Numerical Evaluation of an Adaptive Prestressing System for Crack Mitigation in Bridge Decks. Ibrahim, O., Andrawes, B., University of Illinois, Urbana-Champaign.
- Multi-Bridge Monitoring using MT-InSAR and Machine Learning, Khan, A., Andrawes, B., University of Illinois, Urbana-Champaign
- Full-Scale Testing of an Innovative External Prestressing Bridge Repair Technology using Shape Memory Bars, Gunasekaran, D., Andrawes, B., University of Illinois, Urbana-Champaign.
- Stiffness of Cracked Prestressed Concrete Beams. Lasheen, M., Okumus, P., Elhami Khorasani, N., University at Buffalo.
- Multi-objective Metaheuristic Optimization of Reinforced Concrete Beam for Improved Flexural Performance. Lin, Y., Yan, H., Duan, J., Li, Y., Xiong, X., Guan, S., Tao, C., Purdue University.
- Systematic Investigation of Testing Configurations Toward Standardization of Piezoresistivity-Based Self-Sensing Method for Smart Concrete Structures. Taj, K., Palipana, D., Su, Y., Louisiana State University.
- Enhancing Anchorage Zone Durability in Pretensioned Girders Using Additively Manufactured SHCC Shells: Material Design and Proof-of-Concept Study. Singh, P., Ranade, R., Okumus, P., Zhou, C., University at Buffalo.
- IFC-based Installation Simulation of Precast Bridge Panels in Pre-planning. Soy, M., Hong, Z., Yang, F., Zhang, J., Cai, H., Purdue University.

Additionally, a selection of more regional events, workshops, and conferences with TRANS-IPIC presentations are listed below, highlighting information dissemination and technology transfer.

Selection of Additional TRANS-IPIC Presentations:

- Mazumder, A. and Sarker, B. R. (2025a), “Optimizing Raw Material Ordering Policies for Efficient Precast Concrete Production under Fluctuating Demand and Price,” Presentation ID: 6670, IISE Annual Conference & Expo 2025, Renaissance Atlanta Waverly Hotel & Convention Center (Room: Tyndall), Atlanta, Georgia, May 31- June 3, 2025.
- Mazumder, A. and Sarker, B. R. (2025b), “Optimal Component Allocation on Pallet to Minimize Curing Costs in Precast Manufacturing,” Presentation ID: 8864, IISE Annual Conference & Expo 2025, Renaissance Atlanta Waverly Hotel & Convention Center (Room: Andover), Atlanta, Georgia, May 31- June 3, 2025.
- Hassan Lasheen, M., Okumus, P., Elhami-Khorasani, N. (2025). “An Enhanced and Implementable Machine Learning-Based Evaluation Tool for Prestressed Concrete Bridges.” presentation, PCI Northeast Technical Bridge Committee Meeting, April 24, Sturbridge, MA and online.
- Prestation at PCINE (Precast Concrete Institute North East) Technical Bridge Committee Meeting, Online, April 24, 2025. Authors: Singh, P., Zhou, C., Okumus, P., and Ranade, R. Title: Additively manufactured fiber reinforced shells for concrete bridge durability.
- Presentation at ASU-Swinburne Workshop on Advances in Concrete 3D printing. Authors: Singh, P., Zhou, C., Okumus, P., and Ranade, R. Title: 3D-Printed Concrete Covers for Girder Ends: Advancing Bridge Durability, One Layer at a Time.
- Radwan, I. M., and Dessouky, S. (Sept 18th, 2025). Cool Concrete Sidewalk Pavement: Mitigating Urban Heat Island Effect with Integrating Phase Change Materials, poster presentation at The Texas Civil Engineering Conference (CECON2025), San Marcos, TX.
- Helaly, H., K. El-Rayes, and E.J. Ignacio. (July 2025). “Machine Learning Models for Estimating Construction Costs of Conventional and Accelerated Bridge Construction Methods” ASCE Construction Research Congress (CRC) 2025, Modular and Office Construction Summit (MOC).

2) Research Highlights Webinars: In order to disseminate knowledge acquired on each TRANS-IPIC funded research project, TRANS-IPIC hosts Research Highlights Webinars, where all funded projects present to the broad research team, consortium members, External Advisory Board, Industry Partnership Committee, industry members, and State DOTs. In 2025, projects selected to receive additional funding to continue ongoing research began presenting in February and March of 2025, webinars were not held in April as this is the month of the TRANS-IPIC in-person Workshop. Following the Workshop, Research Highlights Webinars resumed, initially presenting on research projects in their second year of funding, and moving into exploratory projects after each had sufficient time to develop results before sharing with the consortium. All recordings of our Research Highlights Webinars are shared with the community through the center's website and YouTube (see the figure below for reference). These Research Highlights Webinar recordings help connect the center with the community and keep the community aware of the ongoing work by the center. Lastly, TRANS-IPIC is currently in discussions with external industry experts to be included in our monthly webinars, in addition to highlights only center internal research.

In 2025, TRANS-IPIC successfully transitioned our Research Highlights Webinars to now be announced nationally. By this action, our Research Highlights Webinars now target a wider, external audience in addition to the research team and consortium members which regularly attend.

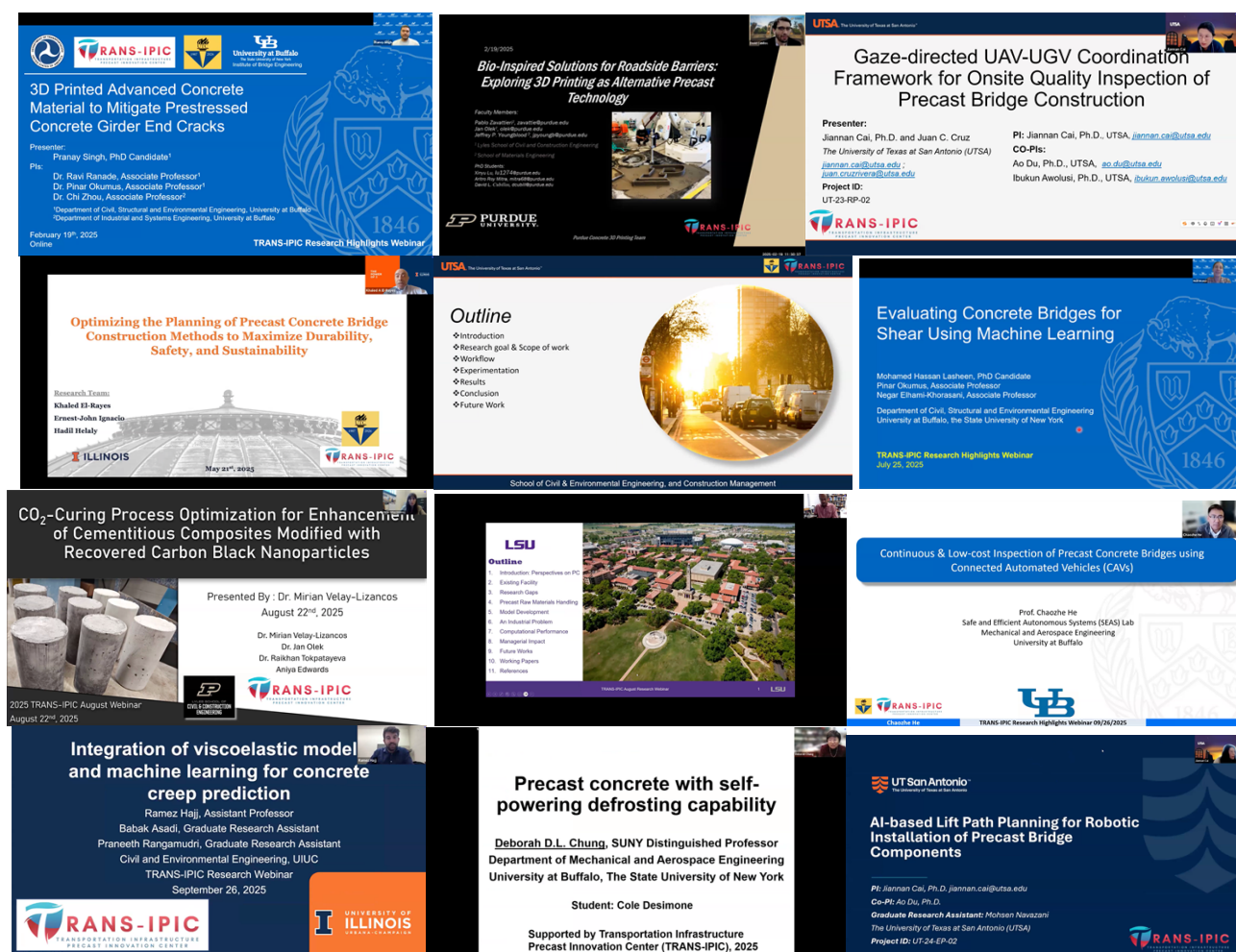


Figure 9. Snapshots from the recorded are available on the TRANS-IPIC UTC Research Highlights Webinars throughout 2025.

a. Plans for the Next Reporting Period

TRANS-IPIC UTC Semi-Annual Progress Report

The next reporting period will focus on:

- 1) TRANS-IPIC is currently conducting out Year 3 Request for Proposal process, throughout the summer and fall of 2025. After September 30th, 2025, TRANS-IPIC will be selecting research projects recommended to be funded during Year 3 of the center. The selected projects will be based on input from external reviewer scores and comments, and the finalized list of recommended projects will be provided to the USDOT for review/approval.
- 2) The TRANS-IPIC Management Team is began planning for our 3rd annual UTC Workshop, immediately following the 2nd annual event. If approved to host this event, TRANS-IPIC will continue the planning and execution of the 3rd annual UTC Workshop for April 2026. As with previous events, in addition to the members of the TRANS-IPIC research consortium we expect transportation professionals, industry members, precast producers, and State DOT members from across the U.S. to attend and collaborate. This event is to include published proceedings with individual DOI for each paper.
- 3) The TRANS-IPIC Management Team is begun initial planning for the 2026 International Symposium on Shape Memory Alloys in Infrastructure. If approved to host this event, TRANS-IPIC will continue dedicated to plan and execute this event dedicated to Shape Memory Alloys in Infrastructure, in order to provide a forum to discuss the state-of-the-art research, emerging applications, and future directions of SMAs in structural, infrastructure, and transportation systems, connecting researchers, engineers, and industry professionals to exchange knowledge on how SMA's unique thermomechanical properties, including superelasticity and shape memory effect, can be utilized to improve the safety, resilience, durability, and adaptability of civil infrastructure. Including published proceedings with individual DOI for each paper.
- 4) In the spring of 2025, TRANS-IPIC will again work with the Grainger College of Engineering and WYSE to be begin the initial planning steps for hosting high school students at the University of Illinois Urbana-Champaign campus in July of 2026, as part of the City Designers and Builders Camp, for the Civil and Environmental Engineering Department.
- 5) Continue disseminating the knowledge created by TRANS-IPIC research projects through conference proceedings and journal papers.
- 6) Leverage strong ties with the industry and partnership committees to promote collaborative projects between TRANS-IPIC and the transportation industry.

2. PARTICIPANTS AND COLLABORATING ORGANIZATIONS

a. Partners

A list of the partners who indicated strong interest in contributing to TRANS-IPIC's activities can be found at (<https://trans-ipic.illinois.edu/team/industry-partners>). The organizations that are involved in the currently funded projects:

- (1) Rinker, Gainey's, Premier Concrete Products, & WASKEY for collaboration and validation
- (2) Louisiana Transportation Research Center (LTRC)
- (3) Terran Robotics
- (4) Sperra (former RCAM Technology)
- (5) Circle Up Indy, Ltd
- (6) AccelNet (Arizona State University, West Pomeranian University of Technology, Poland) MS&T, UT Arlington, University of Puerto Rico)
- (7) Heidelberg Materials
- (8) North Dakota State University
- (9) Atlas Excavating

- (10) Milestone Contractors
- (11) Force Construction
- (12) Kelley Construction
- (13) Walsh Group
- (14) Aldridge Electric
- (15) Superior Construction
- (16) FH Paschen
- (17) Microtek laboratories Company
- (18) City of San Antonio
- (19) Tindall Corporation

b. Other Collaborators

Several individuals from organizations and universities expressed strong interest in the mission of the UTC. They offered to collaborate with TRANS-IPIC in various forms, including reviewing research proposals, delivering training sessions and on-campus seminars to the UTC students. Many of these individuals participated in both Year 1, Year 2, and Year 3 proposal review process which resulted in funded 19 projects in year 1, 20 funded projects in year 2, and a number of proposals for Year 3 which TRANS-IPIC will recommend in the near future.

3. OUTPUTS

a. Publications and Conference papers:

A selection of TRANS-IPIC papers published and those under review for this reporting period.

- Mazumder, A. and Sarker, B.R. (2025a), "Determining optimal variable order quantities of raw materials for precast concrete production considering demand variability and uncertain material prices," Paper-1 (LS-23-RP-04), Submitted to Asia Pacific Journal of Operational Research. 1st submission: September 8, 2025 (APJOR-S-25-00647).
- Mazumder, A. and Sarker, B. R. (2025b), "Optimal vendor-manufacturer cooperative policy for perishable precast materials under stochastic demand and lead-time uncertainty," Paper-4 (LS-23-RP-04), Submitted to International Journal of Production Economics (under review), August 19, 2025 (PROECO-D-25-02726)
- Mazumder, A. and Sarker, B. R. (2025c), "Optimal Vehicle and Resource Allocation for Precast Concrete Transportation under Demand and Travel Time Uncertainty," Working Paper-3 (LS-24-RP-01), Intended for ASCE: Journal of Transportation Engineering.
- K. TajG, Y.-F. Su*, "Durability Evaluation of Economical Self-Sensible Cementitious Composites," Case Study in Construction Materials, 2025 (Under review)
- K. TajG, D. Palipana, Y.-F. Su*, "Systematic Investigation of Testing Configurations Toward Standardization of Piezoresistivity-Based Self-Sensing Method for Smart Concrete Structure", Transportation Research Record, 2026 (Under review)
- Y. Wang, A.E. Douba, J. Olek, P. D. Zavattieri, J.P. Youngblood, Better, Cheaper, Greener: A high-performance Cementitious Composite for Sustainable Concrete 3D Printing, to be submitted to Nature Communications.
- Wang, S., Lin, Y., Duan, J., Yan, H., Wang, X., Xiong, X., Huang, Y., Guan, S., & Tao, C.* (submitted in June, 2025). Intelligent Prediction Framework for Mechanical Response of FRP-Concrete Beam Reinforcement using KAN-based Convolutional Neural Network, Computer-Aided Civil and Infrastructure Engineering.
- Duan, J., Yan, H., Lin, Y., Guan, S., Tao, C. * (submitted in September, 2025). Advanced Structural Health Monitoring and Situational Awareness of Reinforced Concrete Beam using Smart, Self-sensing Composite Reinforcement through Digital Twin Model. Journal of Civil Structural Health Monitoring.
- Wang, S., Wang, X., Duan, J., Yan, H., Huang, Y., & Tao, C.*. (submitted in August, 2025). UNet-based Buckling Deformation Reconstruction from Strain Distributions and Knowledge Distillation. Engineering Applications of Artificial Intelligence.

- Duan, J., Wang, X., Yan, H., Wang, S., Huang, Y., & Tao, C. (submitted in August, 2025). A Damage-informed Digital Twin Framework for Self-sensing Cured-in-place Underground Pipelines. Engineering Structures.
- Hassan Lasheen, M., Okumus, P., Elhami-Khorasani, N., Chandola, V. "Predicting Shear Strength of Prestressed Concrete Beams using Machine Learning." Submitted to the ACI Structural Journal.
- Hassan Lasheen, M., Okumus, P., Elhami-Khorasani, N. (2025). "Evaluation of Structural Cracking in Reinforced and Prestressed Concrete Bridges: A review and a machine learning-based framework." Transportation Research Board (TRB) Annual Meeting, January 5-9, Washington, DC.
- H. Xiao and C. R. He, "Safe and Efficient Data-driven Connected Cruise Control," presented at the 5th Modeling, Estimation and Control Conference (MECC 2025), Pittsburgh, PA, 2025
- Helaly, H., K. El-Rayes, and E.J. Ignacio. (July 2025). "Machine Learning Models for Estimating Construction Costs of Conventional and Accelerated Bridge Construction Methods" ASCE Construction Research Congress (CRC) 2025, Modular and Office Construction Summit (MOC).
- Helaly, H., K. El-Rayes, and E.J. Ignacio. (under review). "Multi-Objective Optimization for the Planning of Prefabricated Bridge Construction Projects" Submitted to the Journal of Construction Engineering and Management, ASCE in August 2025.
- Andrawes, B., Colombani, I., Khan, A. (August 2025). "Using Spaceborne Sensors to Evaluate the Performance of Civil Infrastructure Systems" published in the ASCE Journal of Performance of Constructed Facilities.
- Pérez-Claros, E., Andrawes, B. (July 2025) "Experimental Testing of Concrete Crossties Prestressed with Shape Memory Alloys" Published in the ASCE Journal of Transportation Engineering.

b. Technologies and Techniques:

With SMA technology, TRANS-IPIC is working closely with the industry (Rocla Concrete Ties, Inc.) to develop "smart ties" that can be prestressed at critical regions, which will help solve the problem of center binding cracks that are still haunting PC ties on tracks cutting down their service life span. If cracked under service conditions, the smart tie "heals" itself through the re-activation of the embedded SMA reinforcement using electromagnetic induction. The link provided below showcases a brief video overview of this innovative technology.



<https://uofi.box.com/s/ynpgxwugd04b34mefveeg7we6fzjn9fr>.

4. OUTCOMES

Several of the ongoing and completed TRANS-IPIC projects have resulted in technologies that are ready for implementation. Below are a few examples of these technologies.

- **SMA-CPP Strengthening Technique:** A novel technique for applying external prestressing without mechanical jacking or stressing (see Fig. below).



Figure 10. Innovative technique for externally prestressing bridge girders proposed by TRANS IPIC researchers using smart materials.

- **Shear strength and normalized shear predictions for PC beams:** Bridge owners face difficult decisions on whether a bridge should be posted, repaired or replaced when prestressed concrete (PC) members have shear related cracks due to overloading. The decisions are currently made based on engineering judgment, costly load testing or time consuming and complex modeling. Guidance is needed to interpret cracks and their impact on shear capacity to avoid overly conservative load ratings and to keep bridges operational, without compromising safety and economy. This project developed a reliable and efficient tool through machine learning (ML) to relate cracking to load history of bridge members. Shear strength was also predicted through ML as a reference point for load history. A MATLAB user interface tool that facilitates the use of the ML algorithm in shear capacity predictions has been developed. Additionally, a web application tool created using Python was also developed to provide free access to the tool without the need for a license and enables users to predict shear strength and normalized shear for PC beams. The link to the developed web application is the following: <https://hassan-lasheen.onrender.com/>.

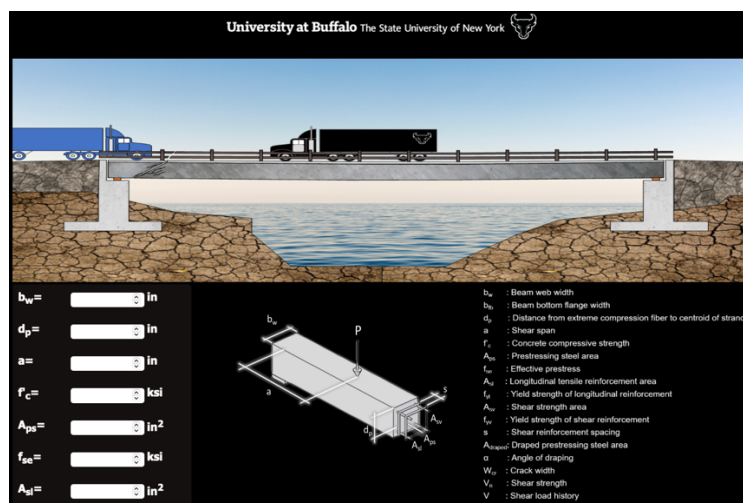


Figure 11: Web application tool created using Python, an open-source programming software, enables users to predict shear strength and normalized shear for PC beams.

- **Multi-objective optimization model to support State DOTs:** The team researching 'Optimizing the Planning of Precast Concrete Bridge Construction Methods to Maximize Durability, Safety, and Sustainability (Phase II)' has developed a multi-objective optimization model to support State DOTs in generating and evaluating optimal trade-offs among four key objectives: maximizing safety, mobility, and sustainability while minimizing the total cost of precast bridge construction projects during the preconstruction phase. The development process involved three main stages: (1) model formulation, which identified all relevant decision

variables, objective functions, and constraints; (2) model implementation, which employed the Nondominated Sorting Genetic Algorithm II (NSGA-II) supported by four additional modules; and (3) model evaluation, which analyzed a case study to demonstrate the model capabilities in optimizing the planning of precast bridge construction projects. This manuscript has been submitted to the ASCE Journal of Construction Engineering and Management on August 1, 2025. This project's final report and publication of this model will help distribute to State DOTs for use.

5. IMPACTS

a. Effectiveness of the Transportation System and Scientific Knowledge

The Twenty (20) funded TRANS-IPIC projects in Year 2, and previously funded Year 1 projects, are working to address critical problems our transportation infrastructure faces. As the center progresses toward closing out Year 2 research, these projects (as well as the projects expected to be funded the ongoing Year 3 RFP cycle) will research innovative ideas and technologies that will help the transportation community improve the durability and sustainability of transportation systems. For example, one of the projects is investigating integrating self-sensing cementitious composites (SSCCs) into 3D-printed precast concrete elements, which combines robotic-based additive manufacturing with embedded sensing capabilities to enable real-time structural health monitoring without relying on external sensors, to improve durability and reduces lifecycle maintenance costs. Another project aims to transform transportation infrastructure, such as bridges and highway sections, into proactive monitors of their own health by leveraging the penetration of connectivity and the advances in vehicle autonomy so the infrastructure can request passing vehicles to continuously and instantaneously collect critical information that exposes signs of structural issues. One of the funded projects will optimize the material used in transportation infrastructure by studying the application of an innovative Adaptive Prestressing System (APS) in a geometrically optimized (truss) Precast Concrete (PC) system to include a shape memory alloy fuse that applies localized prestressing in any direction without mechanical tensioning or special hardware. Another project will develop an innovative framework to characterize and optimize the mechanical, environmental, and economic performance of reinforced precast concrete that will aid in the design of high-performance, sustainable, and cost-effective reinforced precast concrete in order to extend the life of PC transportation infrastructure by providing performance-based optimal solutions based on user's requirements by exploring massive design spaces. A team of researchers is funded through TRANS-IPIC to develop tests and implement a UAV-UGV coordinated inspection system in a pilot precast bridge construction site, identify the practical needs and constraints, and then refine the technology to meet industry expectations for future implementation. Lastly, TRANS-IPIC researchers also show that damage to concrete railway ties can be mitigated using shape memory alloys (SMAs). Ties warped by simulated rail traffic were shown to return to their original state with the help of SMAs activated by induction heating. A University of Illinois Urbana-Champaign news release related to the SMAs usefulness in healing railway tie warpage, here: <https://cee.illinois.edu/news/Alloys-that-remember-their-shape-can-prevent-railroad-damage>.

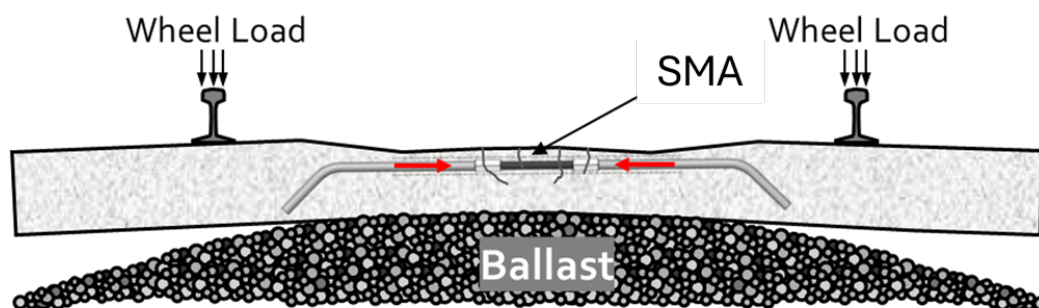


Figure 12: A concrete tie deforming under the weight of rail traffic. The arrow indicates where SMAs were inserted to demonstrate adaptive reinforcement.

b. Transportation Workforce Development

TRANS-IPIC funded projects provide significant opportunities for students and young people in the transportation and related fields. Across all currently funded TRANS-IPIC projects, after a few mid-cycle projects came to close, there are a total of 41 students are supported by TRANS-IPIC-funded projects (8, 4, and 29 undergraduate, MS, and Ph.D. students, respectively) (see **Fig. 13**). Additional students expected to be added when full Year 3 projects are kicked off.

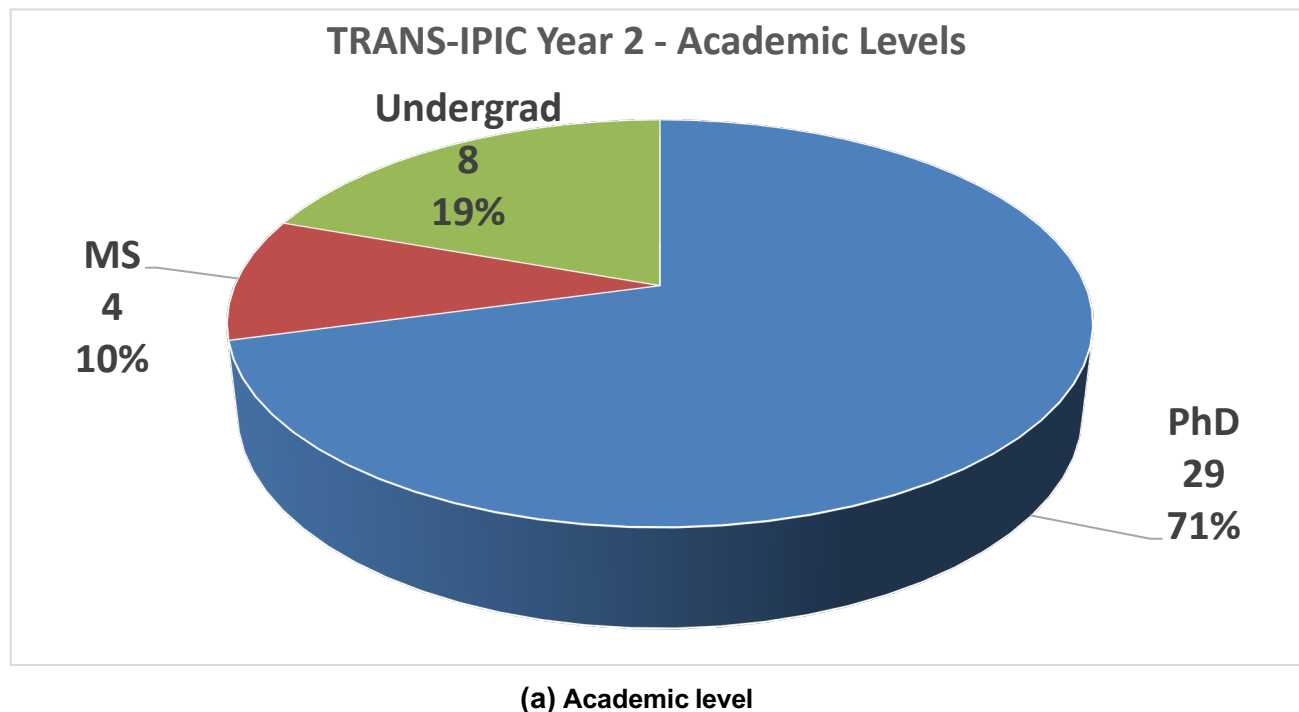


Figure 13. Breakdown of TRANS-IPIC current students based on (a) academic level

6. CHANGES/PROBLEMS

Nothing to Report.

7. SPECIAL REPORTING REQUIREMENTS

Nothing to Report.