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

## Grant No. 69A3552348333

# Transportation Infrastructure Precast Innovation Center (TRANS-IPIC)

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**Submission Date:** November 19th, 2024

**DUNS Number:** 04-154-4081 **EIN Number:** 37-6000511

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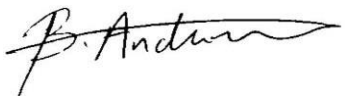
**Unique Entity Identifier (UEI):** Y8CWNJRCNN91

**Project/Grant Period:** 6/1/2023 – 5/31/2029

**Reporting Period End Date:** September 30st, 2024

**Report Term or Frequency:** Semi-Annual

**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) – Minority Serving Institution

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, climate-adaptable, and 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) **Organizing the First Annual TRANS-IPIC Transportation Infrastructure Precast Day (TIP Day):** Among the important activities that took place during this period was the planning for the first Annual Transportation Infrastructure Precast Day (TIP Day) for the TRANS-IPIC UTC. TRANS-IPIC invited all interested students from our consortium to the University of Illinois Urbana Champaign campus on November 01st, 2024. TIP Day is a one-day event where (6x) industry experts associated with TRANS-IPIC will be presenting on the latest technologies in precast concrete (PC) to students. In addition to learning about PC, time is included for students to interface directly with industry professionals. The goal of this event is to show students how PC is shaping the future of our transportation infrastructure. The industry experts presenting at TIP Day are from Utility Concrete Products, The Sherwin Williams Company, Illinois Department of Transportation, HNTB, and PCI of Illinois & Wisconsin.

2) **Organizing TRANS-IPIC Workshop at TRB 2025:** TRANS-IPIC will host a sustainability-focused workshop at the Transportation Research Board (TRB) annual meeting, on Sunday,

January 5, 2025, 1:30 PM-4:30 PM. The TRANS-IPIC Workshop, event (#1045), is titled 'The Role of Precast Concrete in the Sustainability of Transportation Infrastructure: Approaches and Challenges', and is sponsored by the Standing Committee on Concrete Bridge, Standing Committee on Advanced Concrete Materials and Characterization, and the International Coordinating Council. Along with the TRANS-IPIC Director, Dr. Andrawes, speakers from state DOTs, industry, and academia will present and lead session discussions.

3) **Future of Transportation (FoT) Summit:** Members of the TRANS-IPIC consortium attended the Future of Transportation (FoT) Summit in Washington DC on August 13-15, 2024. Members of our consortium presented (3x) posters, hosted a live demo and booth, and the center director (Dr. Andrawes) presented. From the TRANS-IPIC consortium, (2x) faculty and (3x) students attended.

4) **'Building with Memory' Workshop Hosted during Grainger Engineering 'City Designers and Builders' Summer Camp:** On Tuesday, July 23rd, 2024, TRANS-IPIC hosted a 3.5 hour workshop for 10-12th grade high school students. This event was led by center director, Dr. Andrawes, and (7x) graduate students.


**Figure 1.** University of Illinois 'Building with Memory' Workshop event pictures.

5. **'Building Bridges with Memory' Host Six Students During Summer 2024:** TRANS-IPIC collaborated with the Worldwide Youth in Science and Engineering (WYSE) Program and the TRIO Upward Bound Program, to host six high school students during the summer of 2024. Students from underrepresented backgrounds participated in class and lab exercises, multiple sessions per week, for 5 weeks. The TRIO Upward Bound program at the University of Illinois at Urbana-Champaign is housed in the Office of Minority Student Affairs. Upward Bound is committed to providing students with high-quality academic, cultural, and career-related activities designed to prepare and equip them to successfully complete high school, enroll in an accredited post-secondary institution and obtain a baccalaureate degree.

6. **Hosting Monthly Webinars:** Starting in February 2024, TRANS-IPIC began holding monthly webinars where researchers and students are able to share their research findings and discuss how to achieve the goals of the center. Each webinar includes two to three presentations related to the UTC projects. TRANS-IPIC has hosted (7x) Research Webinars, and a total of (17x) information research talks. The recordings from the webinar are shared with the community through our center's website and accessible to all consortium members, industry, and the public (https://trans-ipic.illinois.edu/news/webinars). The webinar attendance is tracked, and a 1.0 Professional Development Hour (PDH) is offered for viewing the session.

7. **Quarterly Progress Reports:** The TRANS-IPIC management team established an online system to collect and survey all researcher teams regarding their projects' quarterly progress reports (QPRs). These Quarterly Progress Reports are reviewed by the center's leadership team, and additional reviewers, to ensure that the funded projects are on the right track. QPRs are rated on each project's progress, and feedback is provided to all research teams. A copy of the QPRs is posted on the TRANS-IPIC's website (https://trans-ipic.illinois.edu/research).

8. **Final Project Reports:** TRANS-IPIC is currently working with funded research teams to collect Final Reports on all funded research projects by Nov. 30th, 2024. These reports will be reviewed by the center's leadership team to ensure all projects met their research goals and can be closed out prior to funding Year 2 projects. A copy of all Final Reports will be posted on the TRANS-IPIC's website (https://trans-ipic.illinois.edu/research). **Table 1** shows the full list of projects funded to date by the TRANS-IPIC UTC including the six newly funded projects highlighted in blue. The funded projects were posted on TRANS-IPIC's website (https://trans-ipic.illinois.edu) and reported to UTC Grant Manager, Ms. Denise Dunn. The funded projects were also posted on the Transportation Research Board's (TRB) Research in Progress (RIP) database.

**Table 1. A List of TRANS-IPIC funded projects during Year 1 to date**

| Project Title | PI Institution & PI Name | Federal ($) | Match ($) |
|---|---|---|---|
| Evaluating Scanning Technology for Process Monitoring and Quality Control in Precast Concrete Fabrication | LSU: Isabelina Nahmens | $64,985.00 | $37,008.00 |
| Design, Manufacturing, and Characterization of Fiber Reinforced Shape Memory Polymer Rebars | LSU: Guoqiang Li | $96,787.00 | $48,400.00 |
| Holistic Quality Management of Precast Concrete Construction for Transportation Infrastructure | Purdue: Hubo Cai | $62,119.00 | $39,865.00 |
| Bio-Inspired Solutions for Jersey and Road Noise Barriers: Exploring 3DPrinting as Alternative Precast Technology | Purdue: Pablo Zavattieri | $67,576.00 | $58,227.00 |
| Unveiling synergistic effects of Nano-modification and CO2 curing on the durability and carbon footprint of precast elements | Purdue: Mirian Velay-Lizancos | $64,092.00 | $40,132.00 |
| 3D Printed Advanced Materials to Mitigate Prestressed Concrete Girder End Cracks | UB: Ravi Ranade | $80,000.00 | $40,000.00 |
| Evaluating Prestressed Concrete Beams with Cracks using Machine Learning | UB: Pinar Okumus | $80,000.00 | $40,000.00 |
| Shape Memory Alloy Transverse Reinforcement for Solving End Region Problems in Precast Bridge Girders | UIUC: Bassem Andrawes | $100,000.00 | $50,000.00 |

| | | | |
|---|---|---|---|
| Innovative Precast Concrete Truss Using Adaptive Shape Memory Prestressing System | UIUC: Bassem Andrawes | $100,000.00 | $50,000.00 |
| Adaptive camber precast concrete girder for deflection mitigation of highway bridges | UIUC: Ann Sychterz | $65,000.00 | $32,500.00 |
| Design and Implementation of Digital Twin Models for Continuous Monitoring and Performance Prediction of Precast Concrete Bridges | UIUC: Volodymyr Kindratenko | $65,000.00 | $32,500.00 |
| Thermally Conductive Pre-cast Concrete Pavement for Urban Heat Island Mitigation | UTSA: Samer Dessouky | $80,000.00 | $40,000.00 |
| Exploring Fungal-Induced Carbonate Precipitation (FICP) for Healing Concrete Cracks | LSU: Hai Lin | $64,999.00 | $32,503.00 |
| Data-driven smart composite reinforcement for precast concrete | Purdue: Chengcheng Tao | $64,996.00 | $325,04.00 |
| Developing a cost-effective, reliable and sustainable PC supply system under price volatility and uncertain materials supply | LSU: Bhaba Sarker | $65,000.00 | $32,508.00 |
| Optimizing the Planning of Precast Concrete Bridge Construction Methods to Maximize Durability, Safety, and Sustainability | UIUC: Khaled El-Rayes | $64,961.00 | $39,888.00 |
| Photogrammetry and LiDAR-Based Precast Concrete Railroad Crossties Abrasion Damage Detections | PU: Shanyue Guan | $53,533.00 | $32,000.00 |
| Gaze-directed UAV-UGV Coordination Framework for On-site Quality Inspection of Precast | UTSA: Jiannan Cai | $65,000.00 | $32,500.00 |
| Investigating the Durability and Resilience of Precast Post-Tensioned Concrete Box Girder Bridges with External Tendons | UIUC: Bassem Andrawes | $69,235 | $34,618 |

**9. University of Texas at San Antonio Featured Research**: As part of the UTSA School of Civil and Environmental Engineering and Construction Management prospective student tours, TRANS-IPIC research is showcased to demonstrate the exciting research projects that can be worked joined.

**Figure 2.** UTSA Features Research event pictures.

10. **Purdue University Summer Undergraduate Research Fellowship (SURF)**: Two undergraduate students participated in the SURF program to gain hands-on research experience and explore advanced education and research careers. Following this 10-week immersive summer research experience, (2x) papers were completed, (1x) research talk, and (1x) poster. Papers are not released yet due to the potential for patents.

11. **Purdue University sessions on the Fundamentals of 3D Printing Technology:** (40x) students attended Purdue's Fundamentals of 3D Printing Technology sessions, where they gained an overview of various 3D printing systems, and toured Purdue's lab space.

12. **Discussions with Purdue University's Women in Engineering (WiE) Program**: Purdue Engineering associated with TRANS-IPIC is currently in discussions with the WiE program to negotiate if 1-week of TRANS-IPIC sessions can be included.

13. **Hosting High School Students at the University at Buffalo**: In the spring of 2024, the University at Buffalo began including examples of TRANS-IPIC research into Machine Learning and 3D Printing Technology for High School students hosted at this institution.

14. **Purdue Promise (program):** In the fall of 2024, TRANS-IPIC-associated faculty took part in the Purdue Promise program. Purdue Promise supports eligible 21st Century Scholars with financial aid and individualized coaching with professional staff to boost academic, social, leadership, and life skill development. They offer resources and support for scholars' transition to Purdue and college, 1:1 meetings with a Student Success Coach, including regular one-on-one coaching meetings with professional staff.

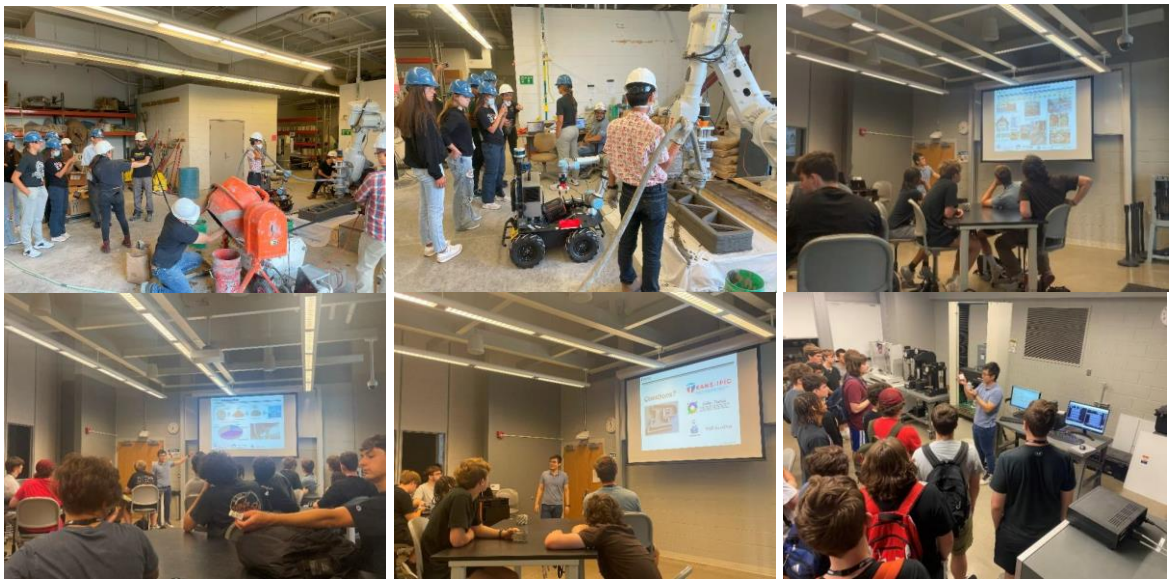


**Figure 3.** Purdue University's Summer College for High School Students event pictures.

15. **Purdue's Superheroes of Science Series:** Purdue research team PI, graduate, and undergraduate students have recently filmed a series of K-12 educational videos about sustainable construction materials and resilient infrastructure posted on YouTube as part of Purdue's Superheroes of Science Series.


**Figure 4.** Purdue's Superheroes of Science Series, video pictures.

16. **Resilient and Sustainable Bridges:** The University at Buffalo research team presented results at the Northeastern Peer Exchange for Resilient and Sustainable Bridges, which took place in Buffalo, NY on August 7, 2024. The event was attended by engineers from departments of transportation, industry, consultants and material producers, as well as academics and students.

17. **Printable SHCC Developed, University at Buffalo:** An undergraduate research intern worked with the UB research team in June and July, 2024. Working alongside the graduate student, he gained vital skills of mixing, processing, casting, testing, and printing fiber-reinforced concrete materials. The undergraduate intern applied artificial neural networks to deduce fundamental rheological properties of SHCC based on the results of rheometer experiments. A key outcome of this research will be the method for developing a printable SHCC. The material development process and the applications of the material to bridges be included in a lecture of the PI's graduate course on Advanced Concrete Materials taught every Spring semester at the University at Buffalo and taken by students and professionals including ones from New York State Department of Transportation.

18. **XCITE and REHAMS Camps at Louisiana State University:** LSU research team partnered with LSU College of Engineering existing summer camps to showcase a TRANS-IPIC UTC project, in particular, how Industrial Engineers can support the Precast industry to improve our Transportation system. The team conducted two sessions during this summer including Recruiting into Engineering High-Ability Multicultural Students (REHAMS) on June 26th, 2024, and eXploration Camp Inspiring Tomorrow's Engineers (XCITE) scheduled for July 17th, 2024. XCITE is a 7-day camp for rising 9th-12th grade female students that encourages them to pursue engineering/computer science/construction management careers in transportation. All girls reside on the LSU campus in a residential hall while supervised by college student counselors. Participants explore, create, experiment, build, code, design, and compete while learning about a variety of engineering majors and college life. LSU faculty and engineering students interact with attendees in Engineering 101 information sessions and activities. REHAMS camp is for 10th-12th grade male and female students from all backgrounds who want to learn about various disciplines of engineering during a 7-day camp while residing on campus.

19. **New Research Projects - Request for Proposals (Year 2):** TRANS-IPIC is currently in the process of conducting the Year 2 Request for Proposal process. (27x) proposal submissions were reviewed during the open call. An external review process is currently underway by experts from the industry who are not affiliated with the UTC. External reviews are scheduled to be completed on Nov. 08, 2024, and the project kickoff is to begin in January 2025.

20. **New Research Projects – 'Exploratory Projects Call for Proposals':** To meet the strategic goals of the USDOT, in parallel with the standard Year 2 Request for Proposals, TRANS-IPIC has also opened a call for seed/exploratory projects in the focused topics of (1) Developing Net-Zero Precast Components for the Transportation Industry, (2) Developing Wireless EV-Charging Precast Components, (3) Precast Concrete Pavement with Self-Powered Defrosting Capability, (4) Design and Fabrication of Precast Elements with Digital Twin and IoT Capabilities, (5) Robotic Production and Installation of Precast Components. Proposals for this call are due mid-November, and selected projects are targeted to start in January 2025.

21. **External Advisory Board Meeting:** In addition to previous sessions discussed on earlier semi-annual reports, the TRANS-IPIC Director, Dr. Andrawes held a meeting with the External Advisory Board (EAB) on June 6th, 2024, and September 16th, 2024. The EAB is formed primarily from State DOT representatives from the States of Illinois, Texas, Indiana, and Louisiana and professional organizations including the American Concrete Institute (ACI), the Precast/Prestressed Concrete Institute (PCI), and the American Segmental Bridge Institute (ASBI). The EAB provided their input and feedback on the activities carried out to date by the UTC. They also offered suggestions related to the program of the workshop and the research projects that the UTC is currently funding, The EAB agreed to meet with the TRANS-IPIC UTC leadership every quarter.

## 1.3. 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 including:

- TRANS-IPIC's own in-person Workshop where members from all funded research teams attended in person and presented to the wider team (presentation or poster)
- CUTC Summer Meeting on South Padre Island
- Illinois Society of Professional Engineers 2024 Virtual Structural Engineering Boot Camp
- MINK (Missouri Iowa Nebraska Kansas) Local Roads Meeting, Northeastern Peer Exchange Resilient, and Sustainable Bridges
- BEFIB 2024 XI International symposium on fiber-reinforced concrete
- UB Institute of Bridge Engineering External Advisory Board, 2024 ASCE International Conference on Computing in Civil Engineering
- USDOT Future of Transportation (FoT) Summit
- International Conference on Transportation and Development (ICTD 2024)
- Graduate Research Conference (GRC), Louisiana State University
- Purdue's Joint Transportation Research Program (JTRP), Indianapolis, IN
- Purdue Road School 2024 poster presentation, West Lafayette, IN
- American Society of Civil Engineers (ASCE) International Conference on Computing in Civil Engineering (i3CE 2024), Pittsburgh, PA
- Purdue Civil and Construction Engineering Research Showcase
- Northeastern Peer Exchange Resilient and Sustainable Bridges, Buffalo, NY
- Seminar talk at the University of Stuttgart, Stuttgart, Germany
- Seminar talk at the University of Wisconsin Madison
- Seminar talk at Laval University, Quebec City, Canada

At the USDOT Future of Transportation (FoT) Summit, members of the TRANS-IPIC consortium attended the Future of Transportation (FoT) Summit in Washington DC on August 13-15, 2024. Our consortium presented (3x) posters, hosted a live demo and booth, and the center director

(Dr. Andrawes) presented. From the TRANS-IPIC consortium, (2x) faculty and (3x) students attended. (see **Fig. 5**).


**Figure 5.** TRANS-IPIC UTC members presenting their work at various transportation-related conferences and meetings.

**2) Monthly Webinar Recordings:** Recordings from the May, June, July, August, and September monthly webinars are shared with the community through the center's website (see **Fig. 6**). These webinar recordings will help connect the center with the community and keep the community aware of the ongoing work by the center. A monthly webinar was not held in April 2024 as all research teams presented during the TRANS-IPIC in person Workshop in Chicago.

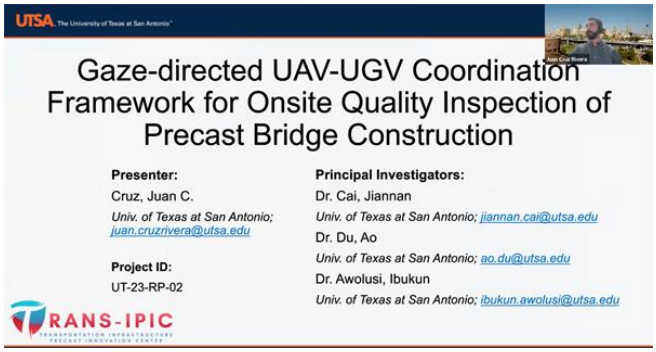




**Figure 6.** Snapshots from the recorded TRANS-IPIC UTC February and March webinars. Recordings are available on the center's website.

### 1.4. Plans for the Next Reporting Period

The next reporting period will focus on:

**1)** Review and provide feedback on the Final Report for all funded projects, to ensure all goals and objectives are met prior to funding Year 2 projects.

**2)** Complete the external review process of proposals submitted for Year 2 and launch projects in January 2025.

**3)** Plan, promote, and host the second Annual TRANS-IPIC workshop to be held in Chicago, IL, in April 2025 and invite researchers and transportation professionals from all over the U.S. to attend the workshop.

**4)** Host the first annual TRANS-IPIC Transportation Infrastructure Precast Day on Nov. 01, 2024, to educate students on the latest technologies in the application of precast concrete (PC) in transportation infrastructure, and offer the opportunity for students to interface directly with industry professionals.

**5)** Host Workshop 'The Role of Precast Concrete in the Sustainability of Transportation Infrastructure: Approaches and Challenges,' on Sunday, January 5, 2025, 1:30 PM-4:30 PM, at the TRB 2025 annual meeting.

**6)** Continue disseminating the knowledge created by TRANS-IPIC research projects through conference proceedings and journal papers.

**7)** Leverage strong ties with the industry and partnership committees to promote collaborative projects between TRANS-IPIC and the transportation industry.

**8)** Start a new series of Seminars/Webinars to be hosted by TRANS-IPIC and announced nationally.

## 2. PARTICIPANTS AND COLLABORATING ORGANIZATIONS

### 2.1. 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). Among the organizations that

are involved in the currently funded projects:

**(1)** Sherwin-Williams, Minneapolis, MN (In-kind material contribution)
**(2)** Illinois Department of Transportation, Springfield, IL (Field testing and data sharing)
**(3)** City of San Antonio, TX (Research partnership)
**(4)** Tindall Corp, Spartanburg, SC (Research partnership)
**(5)** FARO Technologies, Lake Mary, FL (Research partnership)
**(6)** Milestone Contractors, South Bend, In (Project advisory committee)
**(7)** Magnasoft Consulting, Bengaluru, India (Research partnership)
**(8)** Illinois Tollway (Research Partnership)
**(9)** Rocla Concrete Ties, Inc.

### 2.2. 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 and delivering training sessions and on-campus seminars to the UTC students (such as the first Annual TRANS-IPIC Transportation Infrastructure Precast Day on Nov. 01, 2024). Many of these individuals participated in the Year 1 and Year 2 proposal review process which resulted in the currently funded 19 projects, and the projects that will be selected shortly for funding in Year 2 of the center.

## 3. OUTPUTS

### 3.1. Publications and Conference papers:

- Sung M. and Andrawes B. "Innovative Precast Concrete Truss System Using Shape Memory Alloys for Infrastructure Applications" Intelligent Material Systems and Structures. (https://doi.org/10.1177/1045389X241239701) (Federal Funds Acknowledgment: Yes)

- Minsoo Sung and Andrawes B. "Innovative Precast Concrete Truss System Using Shape Memory Alloys for Infrastructure Applications" Intelligent Materials Systems and Structures journal (Accepted). (Federal Funds Acknowledgment: Yes)

- Park S. and Andrawes B. "Damage Mitigation of Prestressed Girders End Regions Using Shape Memory Alloys" 2024 Transportation Research Board Annual Meeting. (Federal Funds Acknowledgment: Yes)

- Park, S., and Andrawes, B. Transverse Prestressing of End Regions of Pretensioned Concrete Bridge Girders, 2025 Structures Congress, Apr. 2025.

- Lasheen, M., Okumus, P., Elhami Khorasani, N. (2024). "Predicting Shear Strength of Prestressed Concrete Beams Using Machine Learning", poster presentation, Transportation Research Board Annual Meeting, presented at the reception by Institute of Bridge Engineering, University at Buffalo, January 7-11.

- Singh, P., Gadde, V.S., Zhou, C., Okumus, P., and Ranade, R. (2024) "3D printed advanced materials to mitigate prestressed concrete girder end cracks" poster presentation, Transportation Research Board Annual Meeting, presented at the reception by Institute of Bridge Engineering, University at Buffalo, January 7-11.

- Y. Wang, A. Douba, J. Olek, J. Youngblood, P. Zavattieri (2024) "Sustainable cementitious

composite containing cellulose nanofibers and limestone filler for concrete 3D-Printing", American Concrete Institute (ACI) Spring 24 convention, New Orleans, LA

- Perez-Claros E. and Andrawes B. "Active Confinement of Precast Concrete Columns using FeMnSi Shape Memory Alloy Hoops" 18th World Conference on Earthquake Engineering, July 2024, Milan, Italy

- Lin, H. (2024). "Harnessing Fungal Mycelia for Sustainable Soil Improvement: Opportunities and Challenges." Biogeotechnics, will submit by mid-October.

- Mazumder, A. and Sarker, B. R. (2024a), "Developing an interpretive structural model for factors affecting cost effectiveness, reliability and sustainability of precast concrete," Working Paper #1 (outcome of QPR-1, January 1 - March 31, 2024).

- Mazumder, A. and Sarker, B. R. (2024b), "Optimizing Pallet Capacity Utilization to Minimize Curing Cost in Precast Concrete Manufacturing," Working Paper #2 (Outcome of QPR-2, April 1 - June 30, 2024).

- Hong, Z., Hong, Y., Cai, H., Abraham, D.M., Zhang, J., Dunston, P.S. (2024). BIM-based framework for in-plant quality control of precast concrete manufacturing - a case study [Under Preparation].

- Y. Wang, J. Olek, J. Youngblood, P. Zavattieri, Biomimetic Sinusoidal Helicoidal Architectures Enhance Strength and Impact Resistance of Additively Manufactured fiber reinforced cementitious composite. Title: Development of 3d printable strain hardening cementitious composites for bridge-related applications".

- Helaly, H., El-Rayes, K., Ignacio, E.J., and Joan, H. J. (Accepted on September 29, 2024) "Comparison of Machine Learning Algorithms for Estimating Cost of Conventional and Accelerated Bridge Construction Methods During Early Design Phase." submitted to Journal of Construction Engineering and Management, ASCE.

- Helaly, H., El-Rayes, K., and Ignacio, E.J. (Under 2nd Review by Editor) “Predictive Models to Estimate Construction and Life Cycle Cost of Conventional and Precast Bridges During Early Design Phase.” submitted to Canadian Journal of Civil Engineering, CSCE, May 2024.

- P. Zavattieri, J. Youngblood, Nature-Inspired 3D Printing for Sustainable Infrastructure: From Design Concepts to Large-Scale Application, 3D Printing Natural Materials to Unlock Complex Nature-Inspired Infrastructure Collaborative Workshop: 7-8 Feb 2024, EWN, US Army Corp of Engineers (RDEC)

- Poster presentation in JTRP posters session on February 22, 2024 in Indiana Government Center South, Indianapolis, IN 46204

- Poster presentation in Purdue Road School 2024 poster session on March 12, 2024 in Purdue Memorial Union, West Lafayette, IN 47906

- Andrawes, B., Sung, M., and Park, S. (In Review) “Behavior of Hot-Rolled Annealed NiTiNb Bars under Full and Partial Heating for Concrete Prestressing Applications” Smart Materials and Structures. (Federal Funds Acknowledgment: Yes)

- Isabelina, N., planned Manuscript on project results submitted to quality management journal such as *Journal of Manufacturing Technology Management* for the topic, 'Evaluating Scanning Technology for Process Monitoring and Quality Control in Precast Concrete Fabrication'

- *Lin, H. (2024). "Harnessing Fungal Mycelia for Sustainable Soil Improvement: Opportunities and Challenges." Biogeotechnics, will submit by mid-October.*

- Hong, Z., Hong, Y., Cai, H., Abraham, D.M., Zhang, J., Dunston, P.S. (2024). BIM-based framework for in-plant quality control of precast concrete manufacturing – a case study [Under Preparation].

- Chengcheng T, "Computational Investigation and Spatial-Temporal Risk Assessment of Reinforced Concrete Failure with Metallic and Composite Reinforcements Transportation Research Board" paper submitted to 2025 TRB convention and is under review.

- Conference paper submitted for TRB Annual Meeting, in January 2025: Hassan Lasheen, M., Okumus, P., Elhami-Khorasani, N. "Evaluation of structural cracking in reinforced and prestressed concrete bridges: A review and a machine learning-based framework."

- A journal paper is under preparation: Hassan Lasheen, M., Okumus, P., Elhami-Khorasani, N., Chandola, V. "Predicting shear strength of prestressed concrete beams using machine learning." In preparation - to be submitted within the next quarter

- Extended abstract was submitted for review at TRB AAMCT 2024 – Transportation Research Board Conference on Advancing Additive Manufacturing and Construction in Transportation, November, 2024. (Under review). Authors: Singh, P., Gadde, V.S., Zhou, C., Okumus, P., and Ranade, R. Title: Development of 3d printable strain hardening cementitious composites for bridge-related applications

- One peer-reviewed conference paper was published and presented at BEFIB 2024 – XI International symposium on fiber reinforced concrete. 15-18 September 2024, Dresden, Germany, pp. 451-458. DOI: 10.1007/978-3-031-70145-0_55. Authors: Singh, P., Gadde, V.S., Zhou, C., Okumus, P., and Ranade, R. Title: Development of 3d printable strain hardening cementitious composites for bridge-related applications".

- Alotaibi, A., Naranjo, M., Henschen, J., and Sychterz A.C. ADAPTIVE CAMBER OF A CONCRETE GIRDER FOR DEFLECTION MITIGATION, Transportation Research Board Annual Meeting 2025, Washington DC (In review).

- Alotaibi, A., Sychterz A.C, and Henschen, J. Computational Modeling of an adaptive concrete highway bridge girder, American Concrete Institute Conference Spring 2025, Toronto, Canada (In preparation).

- Samer, D., Radwan, I., prepared manuscript for submission to Journal of Construction and Building Materials, Sept 2024 (In review).

### 3.2. Technologies and Techniques:

TRANS-IPIC researchers are working on developing and testing innovative and transformative

technologies that can change the future transportation infrastructure. Below are a few examples of the technologies developed/tested to date:

**- Implementation of Smart Railroad Crossties with Shape Memory Reinforcement:** TRAnS-IPIC director and research, Dr. Andrawes utilized the UTC funding to advance the implementation of a new reinforcing technology for railroad crosstie. The new technology is based on incorporating a novel class of smart materials known as shape memory alloys (SMAs) into the critical and vulnerable region in crossties to mitigate cracking and deterioration. Dr. Andrawes utilized the funding to collaborate with Rocla Concrete Ties, Inc., one of the major crosstie producers in North America. He was able to cast several protoptypes at Rocal precast plant and test them at the University of Illinois (see **Fig. 6**). Dr. Andrawes presented a summary of this work at the Inagural U.S. DOT FoT Summit in August, 2024. He is continuing the discussion with Rocla Concrete Ties to further optimizise the design of the ties before testing them on track under dynamic train loads.

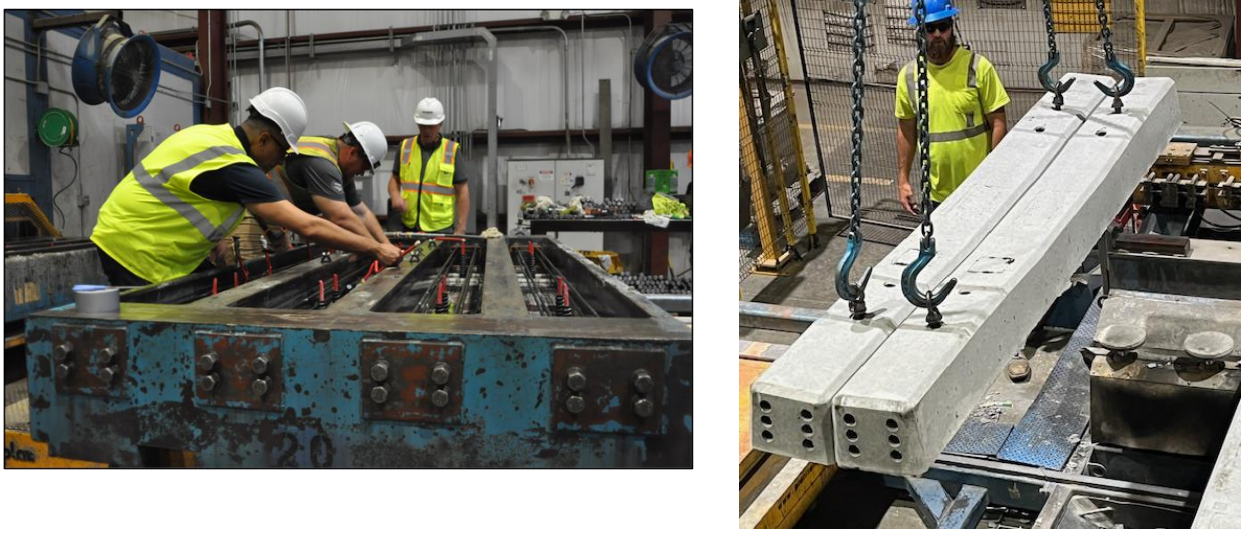


**Figure 6.** TRANS-IPIC researchers and Rocla Concreet Tie staff during the process of fabricating the crossties with SMA reinfororcement.

**- Bio-inspired 3D Printed Road Barriers**: This technology aims at exploring 3D Printing as Alternative Precast Technology' that the first phase of this project aimed to explore the use of 3D printing technology, bio-inspired design, and proper mixture design to enhance the mechanical properties of concrete. These improvements can directly contribute to enhancement of performance of transportation infrastructure, such as roadside barriers.

**- Evaluating Prestressed Concrete Beams with Cracks using Machine Learning:** This project aims to develop software tool that facilitates the use of the machine learning (ML) algorithm in shear capacity predictions of bridge girders. Furthermore, a web-based tool that runs Matlab for ML has been developed. Considering Matlab is a licensed software, a second tool that utilizes an open source programming software (Python) is also being developed for free access to the tool without a license. The tool has become online and incorporated into a website. The tool is being expanded and improved with the latest research findings.

**- New End Region SMA Reinforcement for Bridge Girders:** A new technique was developed, tested experimentally, and validated numerically for mitigating the damage at the end regions of

precast prestressed bridge girders. The technique uses a small number (2 or 3) of stirrups made of shape memory alloys (SMAs) at the end region of the girders. The stirrups can apply considerable internal recovery stress to mitigate the damage that is often observed at the end region due to the transfer of prestressing force in the longitudinal direction. **Figure 7** shows the fabricated specimens during testing at the University of Illinois.


**Figure 7.** Test specimens with embedded SMA end region reinforcement

**- Thermally Conductive Pre-cast Concrete Pavement for Urban Heat Island mitigation:** Our technology aims to introduce Phase Changing Materials (PCMs) in the precast concrete pavement to mitigate temperature fluctuations. The field implementation and monitoring phase (see **Fig. 8**) has been successfully completed, focusing on the real-world performance of PCM-enhanced concrete in mitigating temperature fluctuations in pavement applications.


**Figure 8.** Outdoor experiments, (a) During day, (b) During night.

### 3.3 Inventions and Patent Applications:

- Andrawes, B., Concrete product comprising an adaptive prestressing system, and method of locally prestressing a concrete product.

- Andrawes, B., Method to strengthen or repair concrete and other structures
- Youngblood, J. P., Olek, J., Zavattieri, P. D., Wang, Y., Douba, E. A., Low Carbon, Low-Cost Cement Mix Containing Cellulose Nano Fiber and Limestone Filler For 3D Concrete Printing, under review

- Zavattieri, P. D., Youngblood, J. P., Olek, J., Wang, Y., Energy-Absorbing Roadside Barriers Using Bio-Inspired Architecture and 3D Concrete Printing

# 4. OUTCOMES

The research that TRANS-IPIC researchers have been working on to date is helping in advancing the knowledge pertinent to the the tecniologies that can be implemented in PC transportation components to boost their durability. With more than 25 publications and over 15 major events (conferecnes, workshops, camps, etc.), our researchers are reaching a wide range of audiences from transporation professionals to K-12 studnets passing through college students. The findings and outcomes of the TRANS-IPIC projects include the use of innovative and exciting smart materials like shape memory alloys (SMAs) to working with nano materials to improve the durability of transportation infrastructure. For example, our research on SMAs showed that we can develop concrete with “self-healing” capability, a concept that we plan to further investigate and implement in real transportation components. Our researchers are using 3D printing technology in ana innoavtove way to develop bio-inspired components as well as components with enhanced durability features. The CO2 curing process we are developing is making concrete used in transportation infrastructure more sustainable. The new reinforcement detailing technique for bridge girders can impact the specifications and guidelines adopted in practice to reinforce precast bridge girders. The new detailing method will help solve the problem associated with a prevalent type of damage at the girders' end regions, namely, end splitting cracking.

# 5. IMPACTS

## 5.1. Effectiveness of the Transportation System and Scientific Knowledge

The TRANS-IPIC management team will be collecting the Final Reports for all Year 1 funded research projects at the end of Nov. 2024. Currently, TRANS-IPIC funded (18x) Research Projects and (1x) Industry Partnership Project. Please see **Table 1.** These projects address critical problems our transportation infrastructure faces. Similarly, the external review process of proposals submitted for Year 2 is currently underway and will be launched in January 2025. These projects will identify and implement technologies that will help the transportation community improve the durability and sustainability of transportation systems. For example, our research projects will aid the following topics: Smart Materials, Digital Twin Models, Carbon Emission, Scanning technologies, Remote Sensing, 3D Printing, Building Information Management (BIM), Construction Materials, Machine Learning, Phase Changing Materials, Shape Memory Alloys and Polymers, Nanomaterials, Robotics, Railroad Ties, Ultra-High Performance Concrete (UHPC), Smart Sensing and Monitoring, BIM-Based Quality Control, Adaptive Structures, Self-Healing Concrete, Bio-Inspired Precast Technology, LiDAR-Based Damage Detection.

## 5.2. Transportation Workforce Development

As detailed above in section 1.2, Activities During This Period, all universities comprising the Transportation Infrastructure Precast Innovation Center (TRANS-IPIC) held educational and outreach activities. The team strived over during 2024 to involve interested students, as young as middle school, up through including TRANS-IPIC insights into graduate-level courses.

During the summer of 2024 (06/2024-08/2024), the research team collaborated with two Purdue Summer Undergraduate Research Fellows and industry partner Terran Robotics on projects focusing on sustainable earth-based materials and additive manufacturing technology. This research project enables students to explore the impact of novel materials and technologies on the development of general and transportation infrastructures.

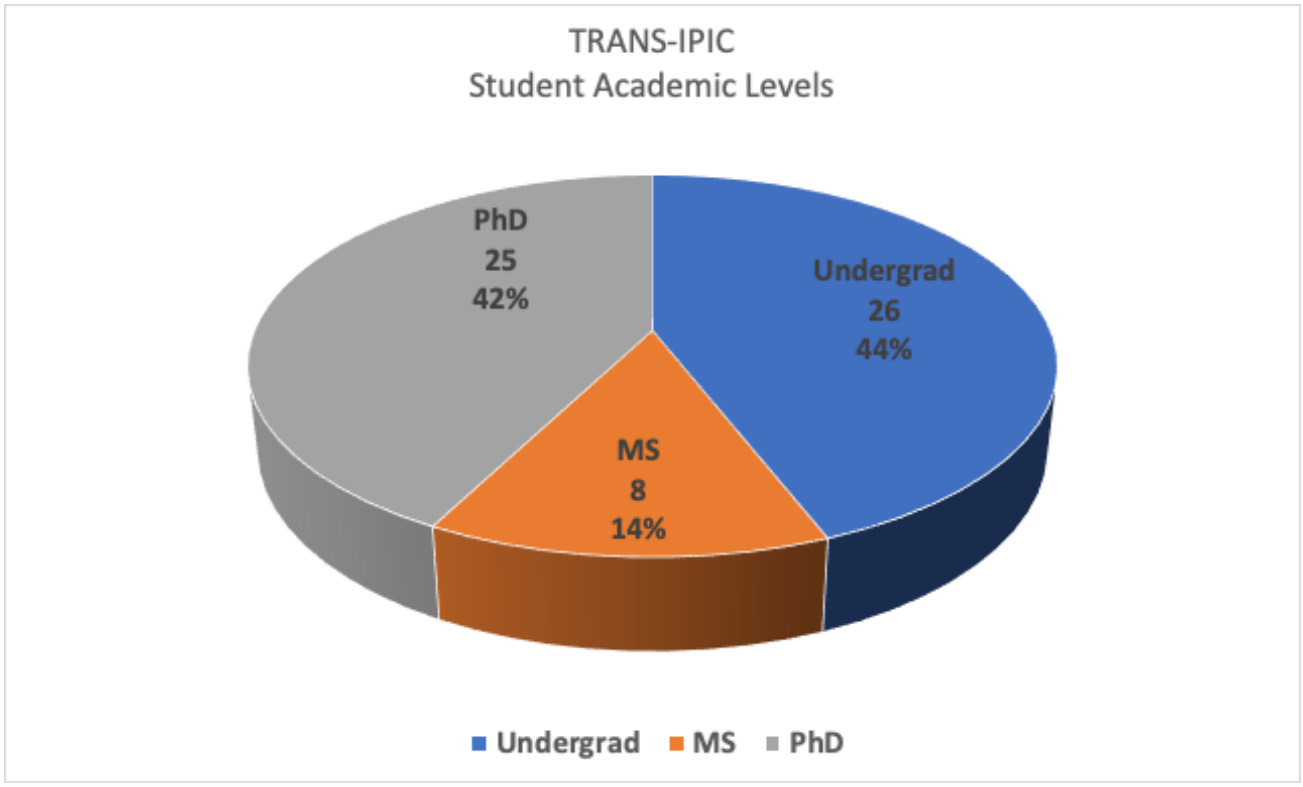
The 18 TRANS-IPIC-funded projects provided significant opportunities for students and young people in the transportation and related fields. Over the last eight months, a total of 59 students have been supported by TRANS-IPIC-funded projects (26, 8, and 25 undergraduate, MS, and Ph.D. students, respectively) (see **Fig. 10**). Among these students, 39% are from minority and under-represented groups.

## 6. CHANGES/PROBLEMS

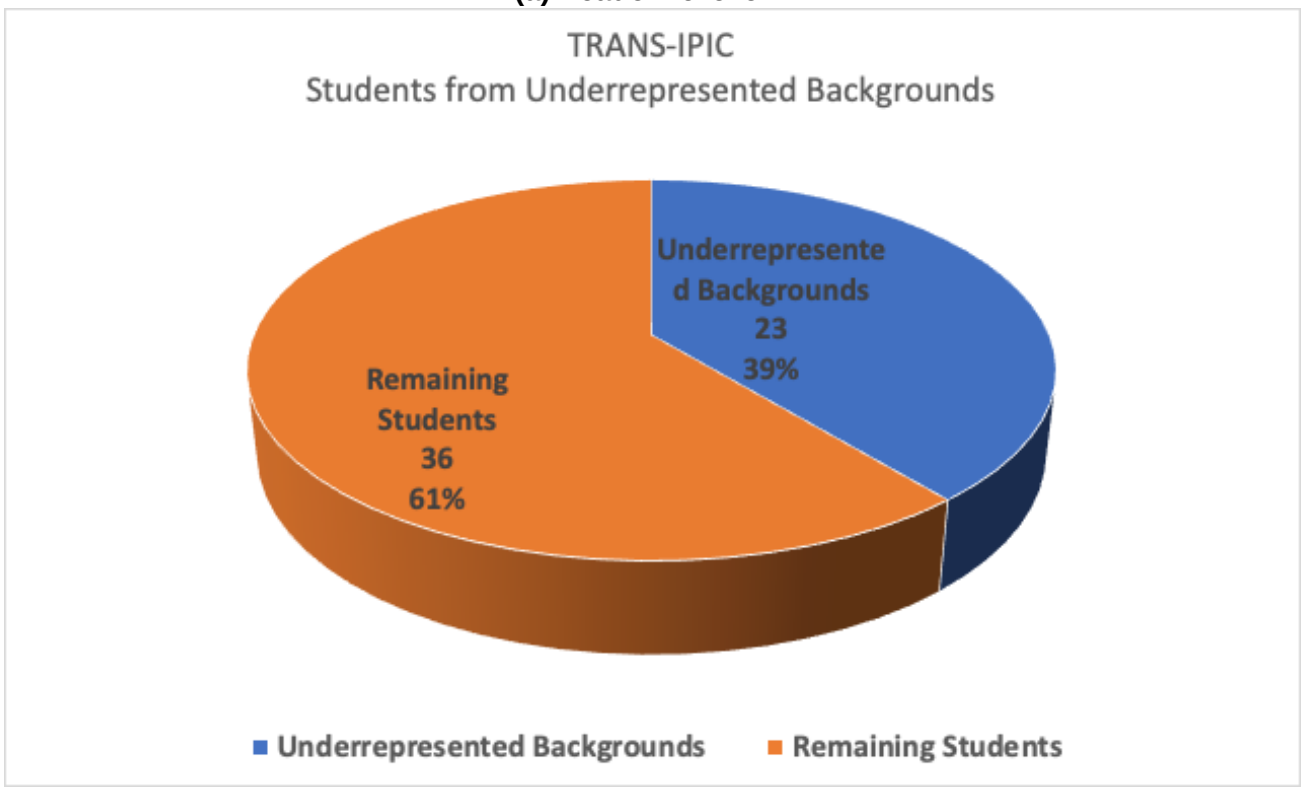
Nothing to Report.

## 7. SPECIAL REPORTING REQUIREMENTS

Nothing to Report.




**(a) Academic level**




**(b) Minority students**

**Figure 9. Breakdown of TRANS-IPIC current students based on (a) academic level and (b) underrepresented and minority groups**