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Transportation Infrastructure Precast Innovation Center (TRANS-IPIC)

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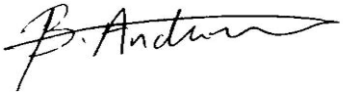
Signature of Submitting Official: 

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) – 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) Kickoff Meeting: Attended on June 5th, 2023, the UTC Grant Kickoff meeting at the U.S. DOT Headquarters in Washington, DC. During the meeting, TRANS-IPIC Director Dr. Andrawes gave an overview presentation about the newly established UTC, including its goals and planned activities.

2) CUTC Meeting: Dr. Andrawes attended the CUTC meeting that was held on June 21st and 22nd in Miami, FL.

3) Website: A new website for TRANS-IPIC was developed and launched in May 2023. The website address was shared with the UTC Grant Manager, Ms. Denise Dunn.

4) Research Proposals: An internal request for proposals (RFP) was issued for all researchers affiliated with TRANS-IPIC in late May 2023 to identify the projects that will be funded during the first year. As a result, twenty-one (21) proposals were received from all five institutions. The proposals were subjected to an external review process by experts from academia and industry

who are not affiliated with the UTC. The review process resulted in funding twelve (12) research proposals from all five institutions (see **Table 1**). The starting date of the funded projects was September 1st, 2023. The funded projects were posted on TRANS-IPIC's website (https://trans-ipic.illinois.edu) and reported to UTC Grant Manger, 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 Round 1 funded projects

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
Desing, 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

5) Future Research Proposals: Plans for the next cycle of RFP were put together during September 2023. A second RFP will be issued during the fall of 2023, with an anticipated starting date of the funded projects as January 1st, 2024.

6) Partnerships: Three committees were formed to connect TRANS-IPIC with the stakeholders and experts from both industry and academia: **(1)** External Advisory Board (EAB): The EAB is formed primarily from State DOT representatives and professional organizations (e.g., ACI, PCI, ASBI). **(2)** Industry Partnership Committee (IPC): The IPC is mainly formed of experts from different sectors of the transportation industry specialized in the application of precast concrete technology in transportation infrastructure. **(3)** Faculty Partnership Committee (FPC): The FPC comprises experts from academia in precast concrete and its application in transportation infrastructure. A total of thirty (30) partners have officially committed to serve on these three committees to date. A list of TRANS-IPIC committee member and partners to date can be found at: https://trans-ipic.illinois.edu/team/industry-partners

1.3. Dissemination

During this reporting period, TRANS-IPIC researchers participated in the following two events to increase awareness in the community about the new UTC goals and activities:

1) Federal and State Dignitaries Visit: TRANS-IPIC UTC director and students participated on July 31st, 2023 in a visit by U.S. Secretary of Transportation and U.S. Congress representatives to the University of Illinois at Urbana-Champaign. Dr. Andrawes and TRANS-IPIC students gave an overview of the new UTC and its goals during the visit. TRANS-IPIC researchers showcased several technologies they are studying (see **Fig. 1**).

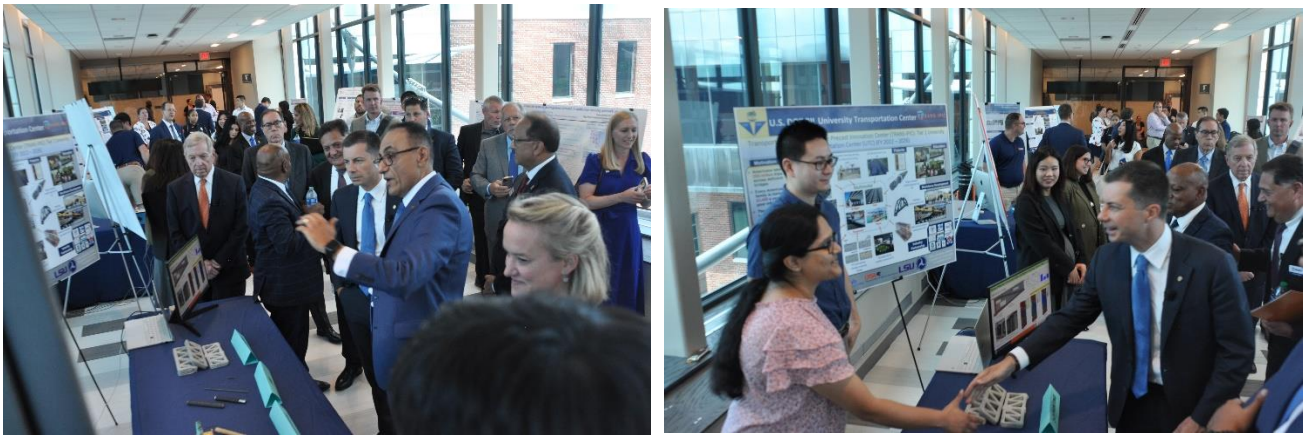


Figure 1. Photos from the visit of the federal and state dignitaries to UIUC and TRANS-IPIC UTC

2) Highway USA Conference: The TRANS-IPIC UTC director was invited to lead a roundtable discussion at the 2023 Highway USA conference that was held on October 4-5, 2023 in Dallas Texas (https://www.terrapinn.com/exhibition/highways-usa/index.stm). The discussion focused

on the main theme of the center: “Improving Durability and Extending the Life of Transportation Infrastructure”. Faculty, students, and staff from UIUC, PU, and UTSA participated in the discussion. They also showcased the technologies and research conducted at TRANS-IPIC through a booth (see **Fig. 2**). This two-day conference was effective in promoting the mission of the new UTC and encouraging many experts from the transportation industry to get involved in the future UTC activities.

Figure 2. TRANS-IPIC representatives at the 2023 Highway USA conference

1.4. Plans for the Next Reporting Period

The next reporting period will focus on:

1) Complete the external review process of the second cycle of proposals and start the new projects in January 2024.

2) Evaluate the performance and impact of the funded research projects by reviewing their quarterly reports.

3) Plan for monthly webinars for TRANS-IPIC affiliates to share their research findings.

4) Organize the first annual in-person TRANS-IPIC workshop in Chicago, IL, in April 2024.

5) Disseminate the knowledge created by the UTC through conference proceedings and journal papers.

6) Leverage strong ties with the industry and partnership committees (EAB, IPC, and FPC) to promote collaborative projects between TRANT-IPIC and the transportation industry.

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)

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. Many of these individuals participated in the first cycle of proposal reviewing that resulted in the funding of 12 projects.

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* (Submitted). (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* (Accepted). (Federal Funds Acknowledgment: Yes)

- 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

3.2. Technologies and Techniques:

- New End Region Reinforcement: A new technique was developed 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 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. Plans for validating this new technique experimentally are underway.

4. OUTCOMES

The new reinforcement detailing technique for the end region (see TRB paper above) can impact the specifications and guidelines adopted in practice to reinforce precast bridge girders. The new detailing method (see **Fig. 3**) will help solve the problem associated with a prevalent type of damage at the girders' end regions, namely, end splitting cracking.

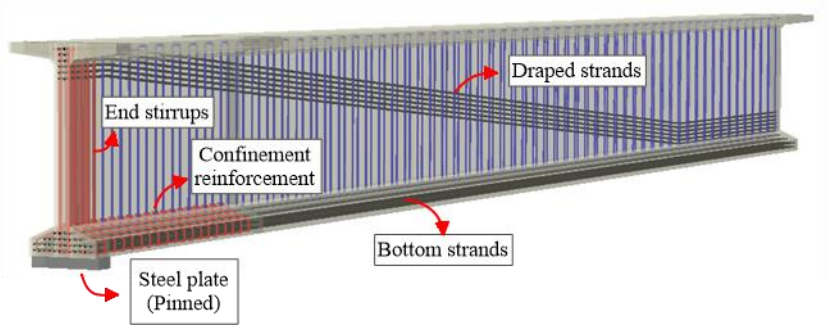


Figure 3. New detailing technique proposed by TRANS-IPIC researchers for PC bridge girders using shape memory alloys

5. IMPACTS

5.1. Effectiveness of the Transportation System and Scientific Knowledge

The twelve (12) funded TRANS-IPIC projects that started on September 1st, 2023 (see **Table 1**) address critical problems our transportation infrastructure faces. Over the next year, these projects (as well as the projects expected to be funded this fall from the second 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 will develop digital twins for PC bridges. The project is expected to facilitate the exchange and analysis of data crucial for evaluating safety risks associated with transportation systems. Another project will develop thermally conductive precast concrete pavement that can reduce the Urban Heat Island effect, enhancing safety and livability for urban residents. One of the funded projects will provide the transportation industry with a novel Adaptive Prestressing System using smart materials to develop geometrically complex PC components with low embodied CO_2. Another project will develop a new method for reducing cracking in precast-prestressed concrete bridge girders using 3D-printable advanced concrete material. A team of researchers is funded through TRANS-IPIC to develop novel Building Information Models (BIM) to ensure the quality of precast components used in the transportation infrastructure. TRANS-IPIC researchers are also studying the adoption of 3D-printed Jersey barriers and acoustic metamaterials that will significantly improve road safety and infrastructure resilience. A project funded by TRANS-IPIC is also investigating the application of nanomaterials and CO_2 curing techniques that can enhance the sustainability and durability of precast elements used in transportation systems.

5.2. Transportation Workforce Development

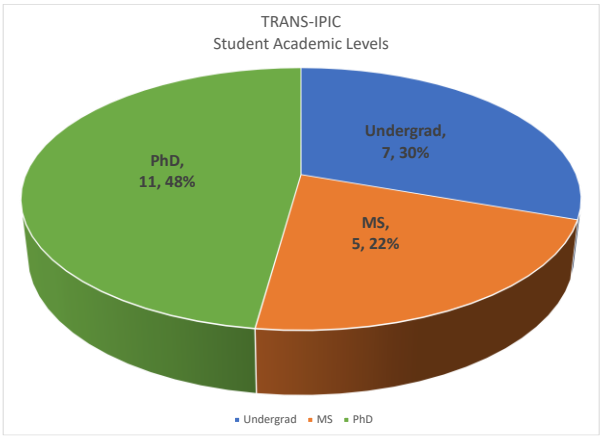
The recently started TRANS-IPIC funded projects (started on September 1st, 2023) provide significant opportunities for students and young people in the transportation and related fields. Over the last two months, a total of 23 students have been supported by TRANS-IPIC funded projects (7, 5, and 11 undergraduate, MS, and Ph.D. students, respectively) (see **Fig. 4**). Among these students, 43% are from minority and under-represented groups.

6. CHANGES/PROBLEMS

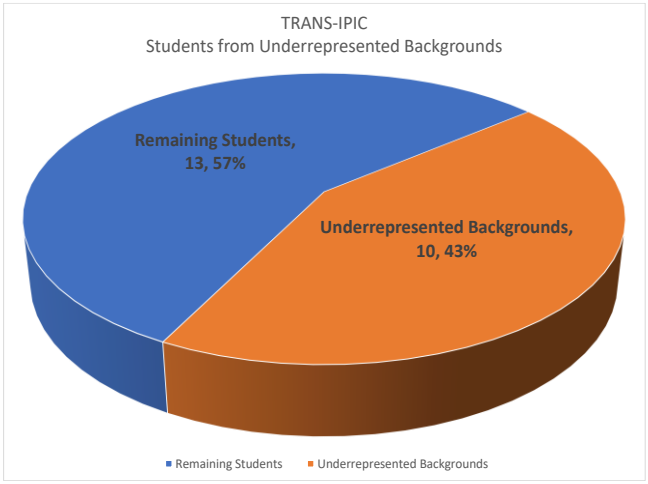
Nothing to Report.

7. SPECIAL REPORTING REQUIREMENTS

Nothing to Report.



(a) Academic level



(b) Minority students

Figure 4. Breakdown of TRANS-IPC current students based on (a) academic level and (b) underrepresented and minority groups