Transportation Infrastructure Precast Innovation Center (TRANS-IPIC)

University Transportation Center (UTC)

Automated Construction of Concrete Bridge Components With Shape Memory Bars
Project No.: UI-25-RP-01

Quarterly Progress Report
For the performance period ending September 30th, 2026

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Collaborators / Partners:
LX Construction

Submitted to:
TRANS-IPIC UTC
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TRANS-IPIC Quarterly Progress Report:

Project Description:

1. Research Plan - Statement of Problem

This project aims to address the challenge of incorporating prestressing in the automated construction of bridge components without using hydraulic jacking or concrete forms. The approach will utilize existing large 3D concrete printers currently employed in the construction of 3D-Printed Concrete (3DPC) buildings, ensuring that the transportation industry can easily adopt the methods demonstrated. As prestressed concrete elements are commonly used in bridges, this project will introduce an innovative technique for internally prestressing large 3DPC components with complex shapes using rebars made from a novel class of metallic material known as shape memory alloy (SMA). This new reinforcement can be activated (prestressed) through heating. The research will explore induction heating as a potential industrial method for prestressing the SMA bars without the need for direct contact. Overall, this research aims to provide the transportation industry with an efficient and practical method for prestressing structural 3DPC components used in transportation infrastructure.

2. Research Plan - Summary of Project Activities (Tasks)

Task 1. Design of Specimens Using Finite Element Method:
A finite element model (FEM) of bridge girders will be employed to design optimized geometries through an iterative process. The quantity and placement of the SMAs will be varied to determine the optimal use of the material.

Task 2. 3D Printing and Testing of Beam Specimens:
Beam specimens will be manufactured with LX Construction. During the printing process, the SMA and steel reinforcement will be integrated between the layers, eliminating the need for rebar ties or concrete rebar chairs.

Task 3. 3D Printing and Testing of Large-Scale Truss Beam:
This task will focus on 3D printing a relatively large concrete truss with embedded SMA bars. The design of the truss will build upon the results of the previous tasks.

Task 4. 3D Printing and Testing of Topology Optimized Beam:
The specimen for this task will feature a more complex geometry with curved contours compared to the truss beam printed in task 3. The design will be created using topology optimization techniques.

Task 5. Induction Heating for SMA Activation:
Induction heating will be employed to heat the 3DPC specimens in this project. This task will focus on optimizing the design of the coil and the power and frequency of the induction system required to activate SMA bars inside the concrete efficiently.

Project Progress:

3. Progress for each research task

Task 1. Design of Specimens Using Finite Element Method [100% completed]
This task was completed in the previous quarter.

Task 2. 3D Printing and Testing of Beam Specimens: [100% completed]
Both 3DPC beams were painted white to help with visual identification of cracks. Strain gauges were added along both beams on the surfaces closest to the reinforcement. The 3DPC beam with SMA bars required heating to activate the shape memory effect. To achieve this, the beam was placed on two wooden supports, and the coil of the electromagnetic induction heater was aligned against the beam's side (**Figure 1**). The SMA bars were heated in segments from the two opposite sides. The strain gauge measurements indicated that permanent prestressing forces developed in the 3DPC.

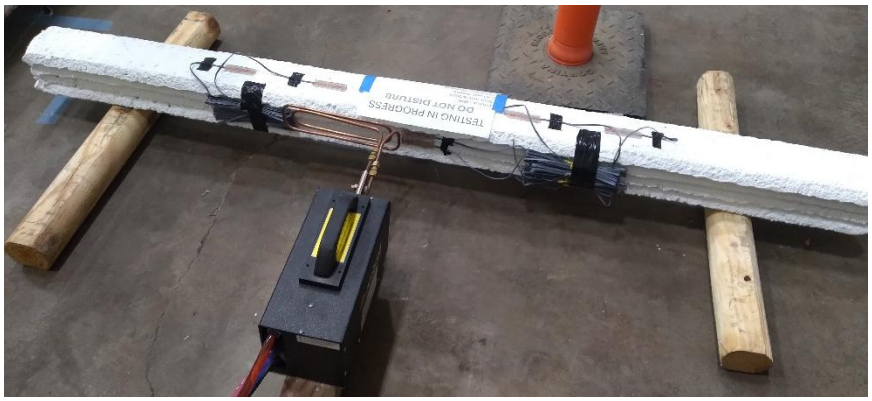


Figure 1. Induction heating setup for 3DPC beam

A 3-point bending test setup was then used to assess the structural performance of the beams. The beam was placed on two metal roller supports and aligned underneath an actuator and load cell. The load was slowly applied to the midspan of the specimen. The 3DPC beam containing only steel reinforcement experienced more localized cracking than the 3DPC beam containing SMAs. Additionally, the onset of cracking in the beam with SMAs was delayed, relative to the beam with only steel.

Task 3. 3D Printing and Testing of Large-Scale Truss Beam: [90% completed]

The side of the test specimen that was cast against the floor during printing had the smoothest surface. Thus, this surface was chosen for use with digital image correlation (DIC). The surface was painted white, and then a speckle pattern was applied to the tension members of the truss. Two concrete footings were cast and then bonded to the test specimen with ultra-high performance concrete (UHPC). These footings allowed the truss to stand upright. Strain gauges were mounted to the back side of the specimen, with most of them concentrated at the tension members, which were the areas of interest.

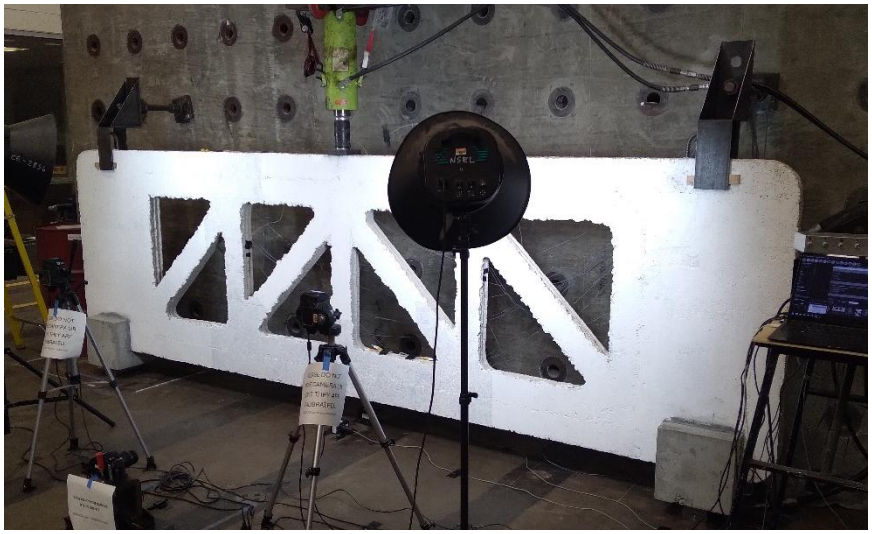


Figure 2. Flexural test setup of 3DPC truss specimen

The electromagnetic induction heater discussed previously was utilized for activating the SMA bars embedded inside the vertical tension member of the truss. A wider coil was equipped so that three bars were heated simultaneously. The DIC and strain gauges indicated that permanent prestressing forces were developed in the tension member. The specimen was then moved to a 3-point flexure test setup, shown in **Figure 2**. The two footings rested on top of two metal half-cylinder supports. The midspan of the truss was aligned under an actuator with a load cell and bearing plate. Two metal braces were added along the top of the truss, above each support. These were provided to resist out-of-plane motion without affecting in-plane motion. Two lights and three cameras were provided to monitor the tension members of the truss.

The pictures were processed with DIC to detect cracks. From the DIC results, it can be determined that the member reinforced with conventional steel rebar cracked before the member reinforced with SMA bars. The member with steel rebar also experienced more severe damage by developing a larger number of cracks. The location of the cracks was also important. The member with steel developed cracks all along its length, whereas the member with SMA developed cracks only at the joints.

Task 4. 3D Printing and Testing of Topology Optimized Beam [50% completed]
Preparation for testing of the topology-optimized beam has started. The smoothest side of the test specimen was painted white to improve visibility of cracks. A speckle pattern was then applied to the tension members of the specimen containing the SMA bars.

Task 5. Induction Heating for SMA Activation: [0% completed]
Nothing to report yet.

4. Percent of research project completed

Total project completed through the end of this quarter = [75% completed to date]

5. Expected progress for next quarter

The expected progress for the next quarter will be testing of the topology-optimized 3DPC beam specimen. This will consist of adding footings and strain gauges to the specimen. Then, the specimen will be prestressed using the induction heater, in a manner similar to the other specimens. Afterwards, the specimen will be tested in flexure to quantify the effects of the SMA bars.

The other task for the next quarter is the induction heating investigation. The main parameter of interest is the coil design. The shape and length of the coil control the size and strength of the magnetic field. This, in turn, affects the heating rate and the heating area. Thus, different coil designs will be fabricated and experimentally assessed to characterize the relationship.

6. Educational outreach and workforce development

A summer camp session for high school students was held on July 29. The session consisted of classroom presentations and demonstrations to explain SMA and 3DPC technologies in transportation infrastructure. The session concluded with a lab tour of the Newmark crane bay, in which students visited the test specimens and setups from this research project.



7. Technology Transfer

Nothing to report yet.

Research Contribution:

8. Papers that include TRANS-IPIC UTC in the acknowledgments section:

Chen, A.; Andrawes, B. Prestressing and Self-Healing of Fiber-Reinforced and Ultra-High-Performance Concrete Using Shape Memory Alloys. Buildings 2026, 16, 1289. https://doi.org/10.3390/buildings16071289

9. Presentations and Posters of TRANS-IPIC funded research:

A presentation on the experimental results of the 3D-printed concrete truss bridge girder prestressed with SMAs was presented at the 1st International Symposium on Shape Memory Alloys in Infrastructure held in Chicago, Illinois on September 17-18.



10. Please list any other events or activities that highlights the work of TRANS-IPIC occurring at your university (please include any pictures or figures you may have). Similarly, please list any references to TRANS-IPIC in the news or interviews from your research.

No additional items to report this quarter.

Appendix 1: Research Activities, leadership, and awards (cumulative, since the start of the project)

A. Number of presentations at academic and industry conferences and workshops of UTC findings
   - No. = 2

B. Number of peer-reviewed publications submitted based on outcomes of UTC funded projects
   - No. = 0

C. Number of peer-reviewed journal articles published by faculty.
   - No. = 1

D. Number of peer-reviewed conference papers published by faculty.
   - No. = 1

E. Number of TRANS-IPIC sponsored thesis or dissertations at the MS and PhD levels.
   - No. MS thesis =
   - No. PhD dissertations = 1
   - No. citations of each of the above =

F. Number of research tools (lab equipment, models, software, test processes, etc.) developed as part of TRANS-IPIC sponsored research
   - Research Tool #1 (Name, description, and link to tool) = None

G. Number of transportation-related professional and service organization committees that TRANS-IPIC faculty researchers participate in or lead.
   - Professional societies
     - No. participated in = 7
     - No. lead =
   - Advisory committees (No. participated in & No. led)
     - No. participated in =
     - No. lead =
   - Conference Organizing Committees (No. participated in & No. led)
     - No. participated in = 1
     - No. lead =
   - Editorial board of journals (No. participated in & No. led)
     - No. participated in = 1
     - No. lead =
   - TRB committees (No. participated in & No. led)
     - No. participated in = 1
     - No. lead =

H. Number of relevant awards received during the grant year
   - No. awards received =

I. Number of transportation related classes developed or modified as a result of TRANS-IPIC funding.
   - No. Undergraduate =
   - No. Graduate = 2

J. Number of internships and full-time positions secured in the industry and government during the grant year.
   - No. of internships =
   - No. of full-time positions = 1

References:

Chen, A.; Andrawes, B. Prestressing and Self-Healing of Fiber-Reinforced and Ultra-High-Performance Concrete Using Shape Memory Alloys. Buildings 2026, 16, 1289. https://doi.org/10.3390/buildings16071289