

**Quarterly Progress Report:**

**Project Number and Title: Project 2.4 - Thermoplastic Composites by 3D Printing and Automated Manufacturing to Extend the Life of Transportation Facilities**

**Research Area: 2 - New Materials for Longevity and Constructability**

**PI: Roberto Lopez-Anido, University of Maine**

**Co-PI(s): James Anderson, Douglas Gardner and Yousoo Han, University of Maine**

**Reporting Period: 04/01/2021 to 06/30/2021**

**Submission Date: 06/30/2021**

**Overview:**

Main activities in this quarter were:

- Unistress Corp., Pittsfield, MA, identified formwork for precast concrete panels that could be 3D printed. Unistress is interested in doing concrete pouring and demolding trials using 3D printed forms to assess longevity.
- Biobased PLA/wood and conventional ABS/carbon composite materials are used to manufacture the formwork.
- A cellular pattern was designed for the formwork to minimize material use, reduce manufacturing time, and reduce costs.
- UMaine started manufacturing 3D printed form for Unistress to assess durability.

**Meeting the Overarching Goals of the Project:**

The activities performed in this quarter supported the following project tasks:

- Task 1.3: Select thermoplastic composite materials and surface finishing for 3D printed forms
- Task 1.4: Design and analyze large-scale 3D printed forms for precast concrete operation requirements
- Task 1.5: Design additive manufacturing, machining and assembly process for large-scale 3D printed forms
- Task 2.1: Manufacture large-scale 3D printed forms for precast concrete construction

**Accomplishments:**

A technical collaboration proposal with Unistress Corp. was funded by the Department of Energy (Phase 1, \$80,000). Unistress will contribute \$40,000 in-kind to the TIDC Project 2.4.

**Task Progress and Budget:**

<b>Table 1.1: Phase 1 - Task Progress</b>			
<b>Task Number</b>	<b>Start Date</b>	<b>End Date</b>	<b>% Complete</b>
Task 1.1: Review of the state-of-the-art	01/01/2019	06/30/2019	100%
Task 1.2: Study the feasibility of using large-scale 3D printed forms for casting precast concrete structures	07/01/2019	12/31/2019	100%
Task 1.3: Select thermoplastic composite materials and surface finishing for 3D printed forms	01/01/2020	03/31/2021	95%
Task 1.4: Design and analyze large-scale 3D printed forms for precast concrete operation requirements	04/01/2020	06/30/2021	90%
Task 1.5: Design additive manufacturing, machining and assembly process for large-scale 3D printed forms	07/01/2020	12/31/2021	100%
Task 2.1: Manufacture large-scale 3D printed forms for precast concrete construction	10/01/2020	06/30/2021	50%
Task 2.2: Monitor concrete casting and demolding operations using 3D printed forms	07/01/2021	09/30/2022	0%

Task 2.3: Disseminate large-scale 3D printed form technology for precast concrete construction	01/01/2021	09/30/2022	0%
Task 2.4: Evaluate durability of 3D printed forms after reuse cycles of casting and demolding concrete operations	10/01/2021	09/30/2022	0%
Task 2.5: Facilitate large-scale 3D printed technology deployment and adoption by specifying material, manufacturing and operational requirements.	07/01/2022	12/31/2022	0%
Phase 1 Overall	01/01/2019	12/31/2021	Phase 1 % Complete
Phase 2 Overall	10/01/2020	12/31/2022	Phase 2 % Complete

**Table 2: Budget Progress**

Project Budget	Spend – Project to Date	% Project to Date*
Phase 1 \$149,912	Enter Phase 1 Full Spend Amount	Enter Phase 1 % Spent
Phase 2 \$158,467	Enter Phase 2 Full Spend Amount	Enter Phase 2 % Spent

\*Include the date the budget is current to.

**Professional Development/Training Opportunities:**

N.A.

**Technology Transfer:**

- Organized meetings with Technical Champion, Rita Seraderian, Precast/Prestressed Concrete Institute Northeast (PCI)-NE and Unistress Corp. (precaster/producer) to identify demonstration studies for large-scale 3D printed forms for precast concrete construction.
- The feasibility of a demonstrations study for the large scale 3D printing technology is currently being investigated: 3D printed form for window screen system in Litewall panel for parking structures.

**Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events**

Title	Event	Type	Location	Date(s)

**Table 4: Publications and Submitted Papers and Reports**

Type	Title	Citation	Date	Status
Conference paper abstract	Design and manufacture of precast concrete formwork using polymer extrusion based large scale additive manufacturing and postprocessing.	Bhandari S., Lopez-Anido, R., Anderson, J. and LeBihan, A. ICAM 2021, ASTM International Conference on Additive Manufacturing, Nov. 1-5, 2021	Mar. 31, 2021	Accepted for presentation



*Figure 1. Felipe Saavedra, MS student in Civil Engineering with 3D printed form assembly*

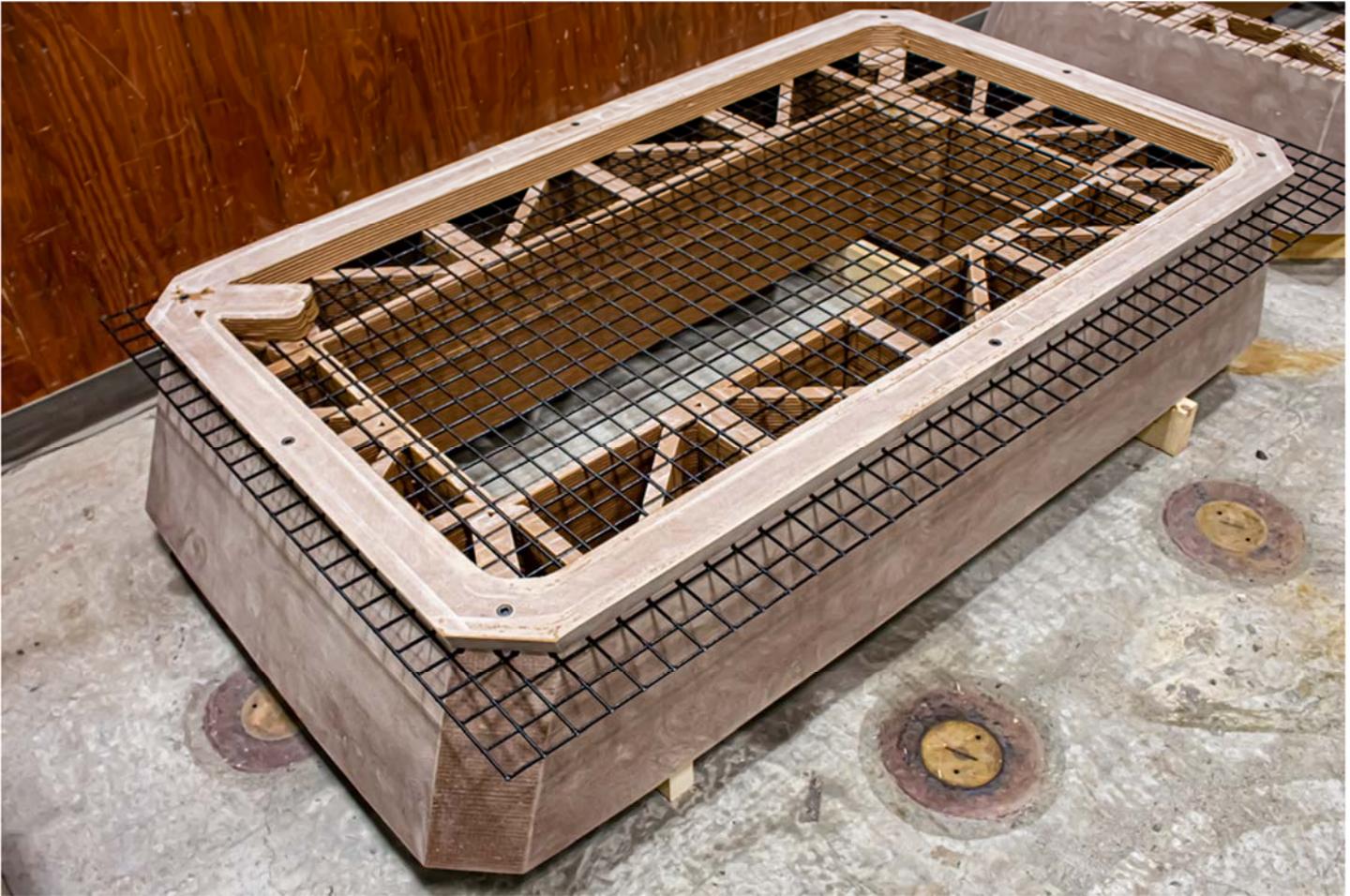


Figure 2. 3D printed form parts for precast concrete panel window opening

**Participants and Collaborators:**

<b>Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members</b>			
<b>Individual Name</b>	<b>Email Address</b>	<b>Department</b>	<b>Role in Research</b>
Roberto Lopez-Anido	<a href="mailto:rla@maine.edu">rla@maine.edu</a>	Civil and Environmental Engineering	P.I.
Douglas Gardner	<a href="mailto:douglasg@maine.edu">douglasg@maine.edu</a>	School of Forest Resources	Co P.I.
James Anderson	<a href="mailto:James.m.anderson@maine.edu">James.m.anderson@maine.edu</a>	Advanced Structures and Composites Center	Co PI
James Bryce	<a href="mailto:James.bryce@maine.edu">James.bryce@maine.edu</a>	Advanced Structures and Composites Center	Project Manager

<b>Table 6: Student Participants during the reporting period</b>				
<b>Student Name</b>	<b>Email Address</b>	<b>Class</b>	<b>Major</b>	<b>Role in research</b>

Sunil Bhandari		Ph.D. Candidate	Civil Engineering	Design the 3D printed formwork, conduct Finite Element Analysis of stresses and deformations, optimize the formwork.
Felipe Saavedra		M.S. student	Civil Engineering	Design and testing of connections. Surface finishing and assembly of forms

**Table 7: Students who Graduated During the Reporting Period**

Student Name	Degree	Graduation Date	Employment or continued degree

**Table 8: Research Project Collaborators during the reporting period**

Organization	Location	Contribution to the Project				
		Financial Support	In-Kind Support	Facilities	Collaborative Research	Personnel Exchanges
MaineDOT	Augusta, ME				x	
Precast/Prestressed Concrete Institute Northeast (PCI-NE)	Belmont, MA				X	
Unistress Corporation	Pittsfield, MA		40,000		X	

**Table 9: Other Collaborators**

Collaborator Name and Title	Contact Information	Organization and Department	Contribution to Research
			(i.e. technical advisory board, test samples, on-site equipment, data, etc.)

**Technical Champion:**

Name: Rita L. Seraderian

Title: Executive Director

Organization: PCI-NE

Location (City & State): Belmont, MA

Email: rseraderian@pcine.org

**Changes:**

The schedule has been affected by disruption of day-to-day laboratory and office work due to the University shutdown in response to COVID-19 health safety precautions.

**Planned Activities:**

During the second quarter of 2021 we plan to work on the following activities:

- Design and manufacture a 3D printed formwork for a precast concrete panel used in parking garage structures.
- Evaluate the performance of the 3D printed formwork through repeated cycles of casting and demolding operations and establish a useful service life for such forms.
- Assess the need for machining and painting for casting and demolding operations, initially as well for reuse of forms. Assess durability of different biobased materials (PLA/wood and PETG/wood) under different exposure conditions during casting and demolding operations, and the dimensional stability under such exposure.