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: *04/01/2020 to 06/30/2020*
Submission Date: *06/30/2020*

Overview:

- We generated a design of a precast concrete pier cap formwork and the toolpath for additive manufacturing.
- We developed a finite element analysis model for the 3D printed formwork.
- We applied the model to optimize the design of the formwork to reduce stresses and deformations due to hydrostatic loads from casting fresh concrete within allowable limits.

The original plan was to 3D print the formwork for the precast concrete pier cap for the Ohio Street overpass of I-95 in Bangor, ME. This was not possible because the COVID-19 closure of the University of Maine. The alternative plan is to 3D print a scaled-down prototype of the formwork to demonstrate the feasibility of the design.

Table 1: Task Progress

Task Number	Start Date	End Date	Percent Complete
Task 1: Review of the state-of the-art	01/01/2019	11/30/2019	100%
Task 2: Optimize forms and tooling for selected precast concrete part	12/01/2019	05/01/2020	90%
Task 3: Select materials and manufacturing process	02/01/2020	07/01/2020	40%
Task 4: Demonstrate the 3D printing tooling for a project	04/01/2020	08/31/2020	0%
Task 5: Recycle and reprint the tooling material	09/01/2020	08/31/2021	0%

Table 2: Budget Progress

Project Budget	Spend – Project to Date	% Project to Date*

An abstract titled “Large scale 3D printed thermoplastic composite forms for precast concrete structures,” co-authored by Sunil Bhandari, Roberto A. Lopez-Anido and James Anderson, was submitted to the 2020 TIDC Annual Conference.

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

Title	Event	Type	Location	Date(s)
Large scale 3D printed thermoplastic composite forms for precast concrete structures	2020 TIDC Annual Conference	Conference	Virtual	August 12-13, 2020

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
Conference paper	Large scale 3D printed thermoplastic composite forms for precast concrete structures	Sunil Bhandari, Roberto A. Lopez-Anido and James Anderson, ITHEC 2020, 5th International Conference on Thermoplastic Composites, Virtual, October 13-14, 2020	June 30, 2020	Submitted

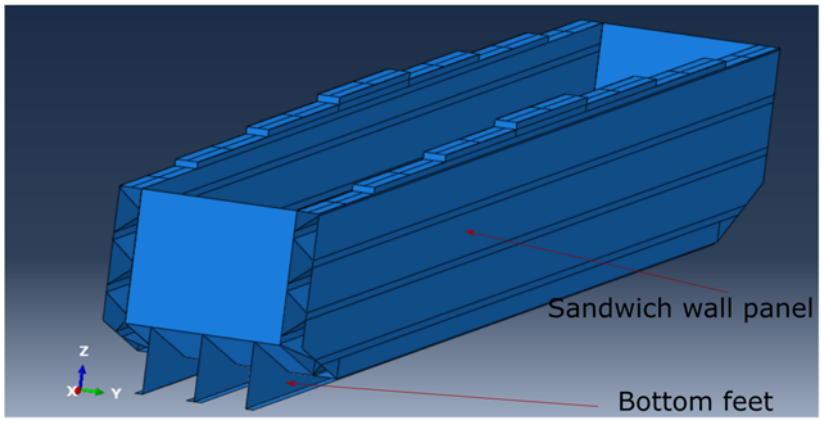

Figure 1: Geometry of the mold used for Finite Element analysis

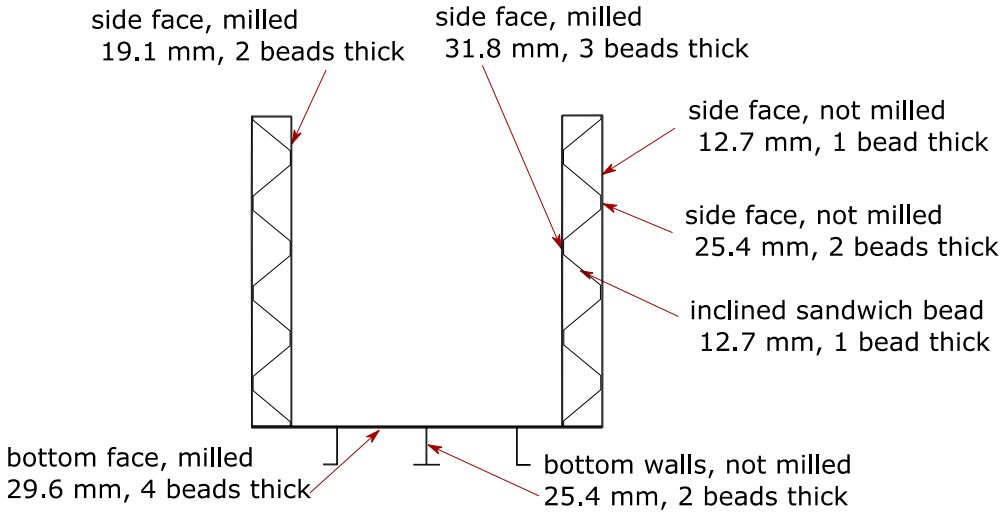

Figure 2: Cross-section of the mold designed for 3D printing

Participants and Collaborators:

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

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
Sunil Bhandari		Ph.D. Candidate	Civil Engineering	Design the 3D printed formwork, conduct Finite Element Analysis of stresses and deformations, optimize the formwork.

Table 7: Student Graduates			
Student Name	**Role in Research**	**Degree**	**Graduation Date**

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**
Precast/Prestressed Concrete Institute Northeast (PCI-NE)	Belmont, MA				X	

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**
Superior Concrete	Auburn, ME				x	
MaineDOT	Augusta, ME				x	
PCI-NE	Belmont, MA				x	

Technical Champion:

Name: Rita L. Seraderian
Title: Executive Director
Organization: PCI-NE
Location (City & State): Belmont, MA
Email Address: 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.

Remote work will continue for design and analysis of the 3D-printed formwork.

Planned Activities:

- We plan to finalize the printing toolpath for the scale-down prototype of the formwork once the software from Ingersoll is available through the Composites Center license server.
- We plan to manufacture the scale-down prototype using UMaine's large-scale 3D printer. This activity is pending the re-starting of lab work at the Composites Center. In addition, the machining work and the assembling of the 3D printed components will be carried out.
- We will assess the quality of the part and characterize any residual deformations, e.g., shrinkage and warping.