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: *07/01/2020 to 09/30/2020*
Submission Date: *09/30/2020*

Overview:

Work performed during the reporting period:

- We designed a demonstration part for manufacturing using the large-scale 3D printer. The part was designed into four segments with a height of 25.5 inches and modeled using SolidWorks. A bio-based renewable material, PLA/wood composite, was selected for the demonstration part.
- The Ingersoll Gen2 slicing software was used to slice the 3D CAD models. Two beads of 0.5-inch thickness and 0.2-inch height were adopted for extruding the demonstration part. The segments were modeled as solid, and the slicer settings were adjusted to deposit two beads on the perimeter. Based on two 3D printing iterations of the part, the design was revised to include a continuous tool path. The next 3D printing attempt is scheduled during the third week of October.
- A work instruction was drafted and approved for application of Pliogrip 7770 adhesive to join the PLA/wood 3D printed segments.

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	12/01/2020	90%
Task 3: Select materials and manufacturing process	02/01/2020	02/01/2021	50%
Task 4: Demonstrate the 3D printing tooling for a project	04/01/2020	05/31/2021	20%
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*
To be completed by Grant/Fiscal Manager, Advanced Structures and Composites Center, UMaine		

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
3D printed thermoplastic composite diffusers for culvert rehabilitation	2020 Student Poster Contest	Poster	Virtual	September 25, 2020
Large Scale 3D Printed Thermoplastic Composite Forms for Precast Concrete Structures	ITHEC 2020 - 5th International Conference & Exhibition on Thermoplastic Composites	Conference	Virtual	October 13-15, 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	Bhandari, S., Lopez-Anido, R.A. and Anderson, J., ITHEC 2020, 5th International Conference on Thermoplastic Composites, Virtual, Emerging Technologies III: 3D Printing – 5, pp. 182-187, October 13-15, 2020 https://ithec.de/	June 30, 2020	Published
Journal paper	Discrete event simulation thermal model for extrusion-based additive manufacturing of PLA and ABS	Bhandari, S., and Lopez-Anido, R., Materials, SI: Additive Manufacturing Methods and Modeling Approaches. https://www.mdpi.com/journal/materials	Sep. 30, 2020	Under review

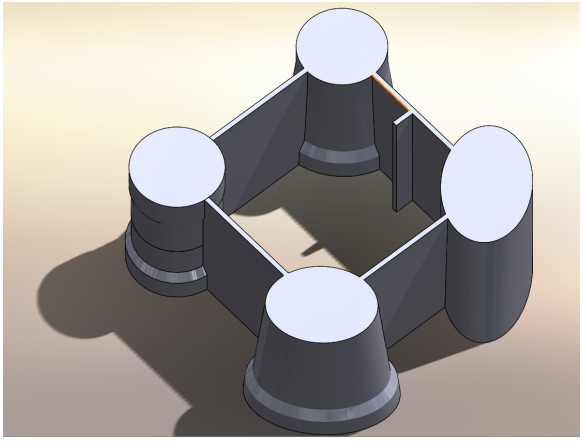
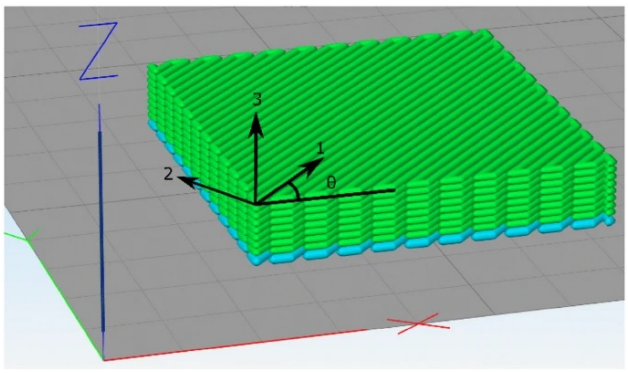


Figure 1: Geometry of the 3D printing demonstration part



Material deposition direction in 3D printing.

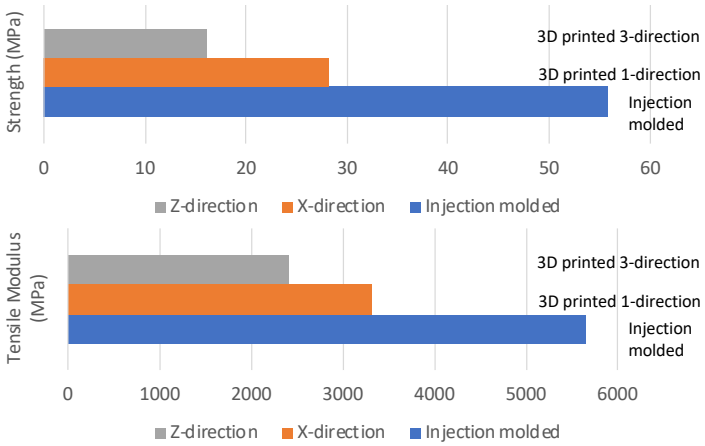


Figure 2: Material properties of PLA-wood 3D printed material

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
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**
N.A.			

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**
MaineDOT	Augusta, ME				x	
Precast/Prestressed Concrete Institute Northeast (PCI-NE)	Belmont, MA				x	

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:

- Meeting with the Technical Champion scheduled at the end of October.
- Finalize the 3D printing toolpath for the scale-down prototype of the precast concrete formwork after the demonstration part is completed.
- Manufacture a scale-down prototype of the precast concrete formwork using UMaine's large-scale 3D printer. This activity is pending the availability of the large-scale 3D printer.
- Demonstrate machining and assembling of the 3D printed components.
- Assess the quality of the 3D printed part and characterize any residual deformations, e.g., shrinkage and warping.