

**Quarterly Progress and Performance Indicators 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, University of Maine

**Reporting Period:** 7/1/2021-9/30/2021

**Submission Date:** 9/30/2021

**\*\*\*IMPORTANT:** Please fill out each section fully and reply with N/A for questions/sections with nothing to report. For ease of reporting to the USDOT, please do not remove, or change the order of, any sections/text. You may remove/add each rows in tables as needed. Thank you! \*\*\*  
The report is due on the last day of the reporting period in .doc format to tidc@maine.edu.

**Overview:**

Provide **BRIEF** highlights of activities performed during the reporting period. This summary should be written in lay terms for a general audience to understand. This should not be an extensive write up of findings (those are to be included in the final report), but a **high-level overview of the activities conducted during the last three months no more than 3 bullet points at no more than 1 sentence each** ....

- Biobased wood/PLA and conventional carbon fiber/ABS composite materials were used to manufacture 3D printed formwork sets for Unistress Corp., Pittsfield, MA, to assess durability.
- A cellular pattern was designed for the formwork to minimize material use, reduce manufacturing time, and reduce costs.
- Large 3D printed formwork system was designed for precast concrete railroad bridge ballast retainer

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

How did the previous items help you achieve the project goals and objects? Please give one bullet point for each bullet point listed above.

- Evaluate the performance of 3D printed formwork through repeated cycles of concrete casting/demolding.
- Assess longevity and establish the useful fatigue life for 3D printed formwork.
- Investigate the cost/benefit of 3D printed formwork, which will be realized provided the material is durable and dimensionally stable.

**Accomplishments:**

List any accomplishments achieved under the project goals in bullet point form...

- Deployed 3D printed formwork prototype at precaster plant to assess longevity during cycles of casting and demolding.

**Task Progress and Budget:**

Complete the following tables to document the work toward each task and budget (add rows/remove rows as needed, make sure you complete the Overall Project progress row and include all tasks even if they have ended or have not been started)...

Table 1.1: Phase 1 - Task Progress			
Task Number	Start Date	End Date	% Complete

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	100%
Task 1.4: Design and analyze large-scale 3D printed forms for precast concrete operation requirements	04/01/2020	06/30/2021	95%
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	60%
Task 2.2: Monitor concrete casting and demolding operations using 3D printed forms	07/01/2021	09/30/2022	10%
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	98% Complete
Phase 2 Overall	10/01/2020	12/31/2022	20% Complete

**Table 2: Budget Progress**

<b>Project Budget</b>	<b>Spend – Project to Date</b>	<b>% Project to Date (include the date)</b>
Enter Phase 1 Full Budget \$149,912	Enter Phase 1 Full Spend Amount (Federal + Cost Share)	Enter Phase 1 % Spent
Enter Phase 2 Full Budget \$158,467	Enter Phase 2 Full Spend Amount (Federal + Cost Share)	Enter Phase 2 % Spent
Enter Phase 3 Full Budget	Enter Phase 3 Full Spend Amount (Federal + Cost Share)	Enter Phase 3 % Spent

**Is your Research Project Applied or Advanced?**

**Applied** (The systematic study to gain knowledge or understanding necessary for determining the means by which a recognized and specific need may be met.)

**Advanced** (An intermediate research effort between basic research and applied research. This study bridges basic (study to understand fundamental aspects of phenomena without specific applications in mind) and applied research and includes transformative change rather than incremental advances. The investigation into the use of basic research results to an area of application without a specific problem to resolve.)

**Professional Development/Training Opportunities:**

Describe any opportunities for training/professional development that have been provided. Did you provide a training to a State DOT/AOT or industry organization? What was the training? When was it offered? How many people attended? Did you meet with a State DOT/AOT or industry organization to inform them of your findings and how these findings could help their organization? When? How many attended the meeting?

- N/A

**Technology Transfer:**

Complete all of the tables below and provide additional information where requested. Please provide ALL requested information as this is one of the most important sections for reporting to the USDOT. **ONLY provide information relevant to this reporting period.**

Use the table below to complete information about conference sessions, workshops, webinars, seminars, or other events you led/attended where you shared findings as a result of the work you conducted on this project:

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events					
Type	Title	Citation	Event	Location	Date(s)
i.e. Conference, Symposium, DOT/AOT presentation, Seminar, etc.	Presentation Title	Full Citation	Name of event (i.e. TIDC 1 <sup>st</sup> Annual Conference) or who was the presentation given to?		
Conference paper presentation slides	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.	ASTM International Conference on Additive Manufacturing	Anaheim, CA,	Nov. 1-5, 2021

Use the table below to report any publications, technical reports, peer-reviewed articles, newspaper articles referencing your work, graduate papers, dissertations, etc. written as a result of the work you conducted on this project. Please list only completed items and exclude work in progress.

Table 4: Publications and Submitted Papers and Reports				
Type	Title	Citation	Date	Status

i.e. Peer-reviewed journal, conference paper, book, policy paper, magazine/newspaper article	Publication title	Full citation		i.e. Submitted, accepted, under review

Answer the following questions (N/A if there is nothing to report):

1. Did you deploy any technology during the reporting period through pilot or demonstration studies as a result of this work? If so, what was the technology? When was it deployed?  
*Yes. A 3D printed formwork prototype was used for multiple cycles of casting and demolding at a precast concrete plant in Veazie, ME, 2021-09-01.*
2. Was any technology adopted by industry or transportation agencies as a result of this work? If so, what was the technology? When was it adopted? Who adopted the technology? *N/A*  
*Yes. American Concrete Industries and MaineDOT*
3. Did findings from this research project result in changing industry or transportation agency practices, decision making, or policies? If so, what was the change? When was the change implemented? Who adopted the change?  
*N/A*
4. Were any licenses granted to industry as a result of findings from this work? If so, when? To whom was the license granted?  
*N/A*
5. Were any patent applications submitted as a result of findings from this research? If so, please provide a copy of the patent application with your report.  
*N/A*
6. Were any industrial contracts awarded base on furthering planned research and development activities as a result of findings from this work? If so, when? How much was awarded? Who awarded the contract?  
*N/A*

*Please add figures/images that can be included on the website and/or in marketing/social media materials to further clarify your research to the general public.*



*Figure 1 – 3D printed formwork prototype after casting concrete*



*Figure 2 – PI Lopez-Anido inspecting 3D printed formwork after casting and demolding at the American Concrete Industries plant*

*Describe any additional activities involving the dissemination of research results not listed above under the following headings:*

**Outputs:**

*Definition: Any new or improved process, practice, technology, software, training aid, or other tangible product resulting from research and development activities. They are used to improve the efficiency, effectiveness, and safety of transportation systems. List any outputs accomplished during this reporting period:*

- Example: New sensing technology was developed. This technology will...
- Designed and manufactured 3D printed formwork for window screen system in Unistress Litewall precast concrete panel for parking structures.

- Designed large 3D printed formwork system for railroad bridge ballast retainer.

**Outcomes:**

*Definition: The application of outputs; any changes made to the transportation system, or its regulatory, legislative, or policy framework resulting from research and development activities. List any outcomes accomplished during this reporting period:*

- Example: The developed sensing technology was installed in Bridge A in town, state on 1/1/2021. This installation will...
- Deployed 3D printed formwork prototype at American Concrete Industries plant in Veazie, ME.

**Impacts:**

*Definition: The effects of the outcomes on the transportation system such as reduced fatalities, decreased capital or operating costs, community impacts, or environmental benefits. The reported impacts from UTCs are used for the assessment of each UTC and to make a case for Federal funding of research and education by demonstrating the impacts that UTC funding has had on technology and education. NOTE: The U.S. DOT uses this information to assess how the research and education programs (a) improve the operation and safety of the transportation system; (b) increase the body of knowledge and technologies; (c) enlarge the pool of people trained to develop knowledge and utilize technologies; and (d) improves the physical, institutional, and information resources that enable people to have access to training and new technologies. List any outcomes accomplished during this reporting period:*

- Example: The developed sensing technology’s successful deployment resulted in the adoption of the technology by the StateDOT. The technology will be installed in all new bridge installments of this type. This adoption will...

**Participants and Collaborators:**

Use the table below to list **all** individuals (compensated or not) who have worked on the project.

<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.
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

Use the table below to list **all** students who have participated in the project during the reporting period. (This includes all paid, unpaid, intern, independent study, or any other student that participated in this project.) **ALL FIELDS ARE REQUIRED.**

**Table 6: Student Participants during the reporting period**

Student Name	Start Date	End Date	Advisor	Email Address	Level	Major	Funding Source	Role in research
				Email is not included in the external report and is only used for internal purposes.	(i.e. Junior, Master's Ph.D)		(i.e. TIDC, University (non TIDC match i.e. study abroad program), unpaid intern, independent study student, etc.	What work are they conducting? Please be descriptive. Student research assistant is not enough info.
Sunil Bhandari	2019-02-01	present	R. Lopez-Anido and D. Gardner		Ph.D. Candidate	Civil Engineering	TIDC	Design the 3D printed formwork, structural analysis and design
Felipe Saavedra	2021-01-01	present	R. Lopez-Anido		M.S. student	Civil Engineering	TIDC	Design and testing of connections. Surface finishing and assembly of forms

Use the table below to list any students who worked on this project and graduated or received a certificate during this reporting period. Include information about the student's accepted employment (i.e. the student is now working at MaineDOT) or if they are continuing their students through an advanced degree (list the degree and where they are attending).

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

Student Name	Degree/Certificate Earned	Graduation/Certification Date	Did the student enter the transportation field or continue another degree at your university?
			Please list the organization or degree

Use the table below to list any students that participated in Industrial Internships:



**Table 8: Industrial Internships**

Student Name	Degree/Certificate Earned	Graduation/Certification Date	Did the student enter the transportation field or continue another degree at your university?
			Please list the organization or degree

Use the table below to list **organizations** that have been involved as partners on this project and their contribution to the project.

**Table 9: Research Project Collaborators during the reporting period**

Organization	Location	Contribution to the Project				
		Financial Support	In-Kind Support	Facilities	Collaborative Research	Personnel Exchanges
		List the amount	List the amount	Mark with an "x" where appropriate		
MaineDOT	Augusta, ME				x	
Precast/Prestressed Concrete Institute Northeast (PCI-NE)	Belmont, MA				X	
Unistress Corporation	Pittsfield, MA		40,000		X	
American Concrete Industries	Veazie, ME			X	X	

Use the table below to list **individuals** that have been involved as partners on this project and their contribution to the project.

*(List your technical champion(s) in this table. This also includes collaborations within the lead or partner universities who are not already listed as PIs; especially interdepartmental or interdisciplinary collaborations.)*

**Table 10: Other Collaborators**

Collaborator Name and Title	Contact Information	Organization and Department	Date(s) Involved	Contribution to Research
	For internal use only			(i.e. technical champion, technical advisory board, test samples, on-site equipment, data, etc.)
Rita L. Seraderian, P.E., FPCI, Executive Director	rseraderian@pcine.org	PCI-NE	2019-02-01 present	Technical champion

Joseph Stilwell P.E., Fabrication Engineer	Joseph.R.Stilwell@maine.gov	MaineDOT-Bridge Program	2021-03-03 present	3D printed formwork for railroad bridge ballast retainer
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Use the following table to list any transportation related course that were taught or led by researchers associated with this research project:

Table 11: Course List						
Course Code	Course Title	Level	University	Professor	Semester	# of Students
i.e. CE 123		Grad or undergrad?	Where was the course taught?	Who taught the course?	Enter Spring, Fall, Summer, Winter and the year	How many students were enrolled in the class?

**Changes:**

List any actual or anticipated problems or delays and actions or plans to resolve them (list no-cost extension requests here)...

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.

List any changes in approach and the reasons for the change...

**Planned Activities:**

List the activities planned during the next quarter.

- Manufacture an additional formwork set
- Ship formwork sets to Unistress Corp.
- 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 biobased material (wood/PLA) and baseline material (CF/ABS) under different exposure conditions during casting and demolding operations, and the dimensional stability under such exposure.