Quarterly Progress Report:

Project Number and Title: 2.11 Culvert Rehabilitation using 3D Printed Diffusers
Research Area 2: New materials for longevity and constructability
PI: Roberto Lopez-Anido, University of Maine
Co-PI(s): James Anderson and Douglas Gardner, University of Maine
Reporting Period: 01/01/2021 to 03/31/2021
Date: 06/30/20

Overview:

Main activities in this quarter were:

- Plan lab testing and material characterization
- Prepare conference paper presentation
- Plan demonstration project with Technical Champion and NHDOT engineers.

Meeting the Overarching Goals of the Project:

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

- Task 1: Initial feasibility study: Design and manufacturing of a 3D printed diffuser prototype for demonstration at a site in Thorndike, Maine
- Task 2: Manufacturing of 3D printed diffuser parts for lab testing and material characterization

Accomplishments:

- **Durability problem:** When corroded culverts are re-lined, then the flow is restricted.
- **Hydraulic solution:** Culvert outlet diffusers can increase the flow by 40%, mitigating roads washing-out after storms.
- **Engineering innovation:** Large scale 3D printing technology enables rapid manufacturing of complex shaped culvert diffusers based on site-specific hydraulic conditions at half the cost than current methods, using bio-based materials.
- **Transportation benefits:** Increasing the drainage flow in culvert relining projects by 40%, avoids millions of dollars spent in complete culvert bridge replacements.
- **Technology implementation:** First 3D printed culvert outlet diffuser to be installed in Maine this summer.

Task Progress and Budget:

<table>
<thead>
<tr>
<th>Task Number</th>
<th>Start Date</th>
<th>End Date</th>
<th>% Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1.1: Initial feasibility study: Design and manufacturing of a 3D printed diffuser prototype for demonstration at a site in Thorndike, Maine</td>
<td>9/1/2020</td>
<td>12/31/2020</td>
<td>100%</td>
</tr>
<tr>
<td>Task 1.2: Manufacturing of 3D printed diffuser parts for lab testing and material characterization</td>
<td>10/1/2021</td>
<td>8/31/2020</td>
<td>30%</td>
</tr>
<tr>
<td>Task 1.3: Material durability evaluation in the laboratory</td>
<td>1/1/2021</td>
<td>8/31/2021</td>
<td>15%</td>
</tr>
<tr>
<td>Task 2.1: Monitoring of the 3D printed diffuser at the site in Thorndike, Maine</td>
<td>10/1/2021</td>
<td>6/30/2022</td>
<td>0%</td>
</tr>
<tr>
<td>Task 2.2: Develop design concepts for 3D printed diffuser systems (Options 1, 2 &amp; 3)</td>
<td>7/1/2021</td>
<td>8/31/2022</td>
<td>0%</td>
</tr>
<tr>
<td>Task 2.3: Commercialization and documentation of the rehabilitation technology</td>
<td>10/1/2021</td>
<td>8/31/2022</td>
<td>0%</td>
</tr>
<tr>
<td>Phase 1 Overall</td>
<td>9/1/2020</td>
<td>8/31/2021</td>
<td>Phase 1 % Complete</td>
</tr>
<tr>
<td>Phase 2 Overall</td>
<td>7/1/2021</td>
<td>8/31/2022</td>
<td>Phase 2 % Complete</td>
</tr>
</tbody>
</table>
Table 2: Budget Progress

<table>
<thead>
<tr>
<th>Project Budget</th>
<th>Spend – Project to Date</th>
<th>% Project to Date*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enter Phase 1 Full Budget</td>
<td>Enter Phase 1 Full Spend Amount</td>
<td>Enter Phase 1 % Spent</td>
</tr>
<tr>
<td>Enter Phase 2 Full Budget</td>
<td>Enter Phase 2 Full Spend Amount</td>
<td>Enter Phase 2 % Spent</td>
</tr>
</tbody>
</table>

*Include the date the budget is current to.

Professional Development/Training Opportunities:

N.A.

Technology Transfer:

Schedule second meeting with NHDOT engineers and Alex Mann (Technical Champion) to plan the design and manufacturing of outlet diffuser for CMP liner and inlet upgrade project, NH 85/Newfields Rd, Exeter - Rocky Hill Brook.

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

<table>
<thead>
<tr>
<th>Title</th>
<th>Event</th>
<th>Type</th>
<th>Location</th>
<th>Date(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large-Scale Extrusion-Based 3D Printing for Highway Culvert Rehabilitation</td>
<td>SPE-ANTEC 2021 Conference</td>
<td>Presentation by Sunil Bhandari, Ph.D. Candidate</td>
<td>Virtual event</td>
<td>May 10, 2021</td>
</tr>
</tbody>
</table>

https://www.4spe.org/i4a/pages/index.cfm?pageID=6478

<table>
<thead>
<tr>
<th>Title</th>
<th>Event</th>
<th>Type</th>
<th>Location</th>
<th>Date(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio-based 3D printed culvert diffusers to reduce roadway storm damage</td>
<td>Hearing on the Climate Resiliency Within the Transportation Industry. Testimony of Dr. Habib J. Dagher, PE</td>
<td>Testimony Before the Subcommittee on Transportation, Housing and Urban Development, and Related Agencies, Committee on Appropriations</td>
<td>Senate Office Building, Washington, DC</td>
<td>May 13, 2021</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Title</th>
<th>Event</th>
<th>Type</th>
<th>Location</th>
<th>Date(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culvert Rehabilitation using 3D Printed Diffusers</td>
<td>TIDC Showcase Presentation</td>
<td>Presentation by Sunil Bhandari, Ph.D. Candidate</td>
<td>Virtual event</td>
<td>May 19, 2021</td>
</tr>
</tbody>
</table>

https://www.tidc-utc.org/events/showcase-presentations/may-2021/

Table 4: Publications and Submitted Papers and Reports

<table>
<thead>
<tr>
<th>Type</th>
<th>Title</th>
<th>Citation</th>
<th>Date</th>
<th>Status</th>
</tr>
</thead>
</table>
Figure 1: printed culvert diffuser (8.5 ft long, 2.5 ft wide) will be installed by Maine DOT to test protection against flooding.

Participants and Collaborators:

<table>
<thead>
<tr>
<th>Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Name</td>
</tr>
<tr>
<td>Roberto Lopez-Anido</td>
</tr>
<tr>
<td>James Anderson</td>
</tr>
<tr>
<td>Douglas Gardner</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 6: Student Participants during the reporting period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Name</td>
</tr>
<tr>
<td>Sunil Bhandari</td>
</tr>
<tr>
<td>Felipe Saavedra</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 7: Students who Graduated During the Reporting Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student Name</td>
</tr>
<tr>
<td>---------------</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 8: Research Project Collaborators during the reporting period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Maine DOT</td>
</tr>
</tbody>
</table>
Table 9: Other Collaborators

<table>
<thead>
<tr>
<th>Collaborator Name and Title</th>
<th>Contact Information</th>
<th>Organization and Department</th>
<th>Contribution to Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timothy S. Mallette, P.E.</td>
<td></td>
<td>NHDOT Specialty Section, Hydraulics</td>
<td>Identified demonstration project and coordinated planning meeting</td>
</tr>
<tr>
<td>Don LeBlanc, P.E.</td>
<td></td>
<td>President DLVEWS, Inc.</td>
<td>Culvert design consultant</td>
</tr>
</tbody>
</table>

Technical Champion:
Name: Alexander Mann
Title: Hydrologist
Organization: MaineDOT
Location (City & State): Augusta, ME
Email: Alexander.Mann@maine.gov

Changes:
The schedule has been affected by disruptions of day-to-day campus and field work due to the University restrictions imposed in response to COVID-19 health safety precautions.

Planned Activities:
The following activities are planned for the next three month period:

• Manufacture 3D printed diffuser parts/plates for laboratory testing and material characterization (Task 2)
• Review the literature and guidelines on environmental durability evaluation of thermoplastic composite materials for large-scale 3D printing (Task 3)
• Select accelerated durability testing protocols in the laboratory (Task 3)
• Identify potential demonstration projects for culvert diffusers in collaboration with MaineDOT (Task 5)