Quarterly Progress Report:
Project Number and Title: Assessment of Micropile-Supported Integral Abutment Bridges
Research Area: Civil Engineering
PI: *Aaron Gallant, Department of Civil and Environmental Engineering*
Co-PI(s): *Bill Davids, Department of Civil and Environmental Engineering*
Reporting Period: *Q3 2020*
Submission Date: *September 30, 2020*

Overview: **(Please answer each question individually)**
*Provide **BRIEF** overview and summary 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 no more than 1 sentence each** ….*

Activities developed during the reporting period include parametric FEA for IAB supported on two different foundations (driven piles and drilled micropiles) at hypothetic cohesive soil layer, as well as, analysis of micro-piles threaded connection strength and stiffness, including literature review of laboratory and field testing of micropiles connections. These tasks were developed aiming to address two major aspects of the project that of interest for the Maine Department of Transportation (MDoT). Those are:

- The necessity to stay in elastic range for micro-piles; i.e. is a plastic hinge detrimental to performance of the bridge and foundation system?
- Failure of the micropile threaded coupling joints, which implies, strength and behavior of threaded joints as well as the failure risk and associated consequences on bridge performance.

The Parametric 2D finite element analyses (FEA) were conducted using the commercial finite element code Plaxis 2D, version 2019. The FEA was intended to analyze the effects of yielding of the piles on the bridge behavior. Three case were considered: (1) Elastic piles fully fixed to the abutments (herein refered as fixed pailes); (2) Elastic piles disconnected at the abutment (disconnected/free piles); and (3) abutments supported on rigid footings (No piles case). The first case represents the piles behaving in the elastic range, while the second case represents a scenario on which rupture of the pile-head takes place as consequence of fatigue failure (repetitive cycles in the inelastic range). The third case serves for comparison purpose, so that contribution of soil stiffness to restraining the abutments can be assessed and distinguished from the pile contribution in the case of disconnected piles. The finite element model uses the same bridge geometric and material properties (girders section, deck thickness, steel and concrete type, among other factors), as well as, same pile sections (H-pile) and considers two soil layouts, namely, frictional and cohesive soils over shallow bedrock. The analysis focusses on bridge deck thermal expansion/contraction, girders and deck deflection and forces, and pile deflections and forces.

To following findings from the parametric study are highlighted:

- Effect of pile fixity at the abutment connections is negligible in the thermal deformations of the bridge-superstructure for cohesive soil scenarios, and slightly greater if rupture takes place on frictional soils scenario, being the thermal expansion/contraction differing only by a maximum of 0.1 in compared with the 0.5 in maximum contraction for winter temperatures.
- Substantial effect of pile top-head condition is introduced into the bridge settlements, being the settlements in the free piles case around 0.5 in for frictional soils, while 0.8 in for cohesive soils. On the other hand, fixed-connection piles models shown around 0.1 in settlement in both, frictional and cohesive soils, which correspond with the pile elastic deformation under compressive load. Despite the increase in settlements for a pile that exhibits rupture at the head, the contribution from the pile is still present, since in the no-piles models the abutment settlements overpassed 1.0 in displacements for the two soil layouts.
- Higher abutment rotations and mid-span bridge deflections were observed for free-piles case as a consequence of reduced restraining action from the piles. This implies 15% higher deflections and 20% higher positive moments, which in the studied cases do not represent any risk for the super-structure performance.
- Pile axial stresses are reduced when rupture takes place, which reduces the risk to extend the damage of the pile to deeper sections.

Regarding the threaded connection failure, the following findings are highlight:

- Two failure modes were identified: connection jump-out and connection rupture. Both of them depict a brittle failure.
- Approach for predicting strength and stiffness of threaded connections was adopted from the literature and validated by comparison with measured moment capacities of 47 tested micropiles reported in the technical literature. Correlation coefficient between predicted and observed moment capacities was $r = 0.98$.
- Hypothesis for the adopted model includes assumption of strain distribution and failure stress for jump-out mode. However, there is no reported data supporting these assumptions nor a described mechanism leading to this failure mode for pure bending loading.
- There is no reported testing of threaded connections failure under combined axial and bending loads. Potential for testing program development focused on these gaps of the knowledge was identified.

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: Task Progress			
Task Number	**Start Date**	**End Date**	**% Complete**
Task 1: Parametric FEA	June 1st 2020	July 31st 2020	100
Task 2: Literature review	August 1st 2020	September 30th 2020	100
Task 3: Matlab programming	August 1st 2020	Spetember 30th 2020	100
Overall Project:	*September 3rd 2019*	*May 2021*	60%

Table 2: Budget Progress		
Project Budget	**Spend – Project to Date**	**% Project to Date***
$186,000		

***Include the date the budget is current to.**

Describe any opportunities for training/professional development that have been provided…

*Describe any activities involving the dissemination of research results (be sure to include outputs, outcomes, and the ways in which the outcomes/outputs have had an impact during the reporting period. Please use the tables below for any Publications and Presentations in addition to the description of any other technology transfer efforts that took place during the reporting period.)… Use the tables below to complete information about conferences, workshops, publications, etc**. List all other outputs, outcomes, and impacts after the tables** (i.e. patent applications, technologies, techniques, licenses issued, and/or website addresses used to disseminate research findings).*

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**
Flexural Strength of Micropile Threaded Connection	TIDC poster contest	Contest	online	October 2020

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
i.e. Peer-reviewed journal, conference paper, book, policy paper	Publication title	Full citation		I.e. Submitted, accepted, under review

Encouraged to add figures that may be useful (especially for the website)…

Participants and Collaborators:

Use the table below to list all individuals who have worked on the project.

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members			
Individual Name	**Email Address**	**Department**	**Role in Research**
Aaron Gallant	aaron.gallant@maine.edu	CIE	PI
Bill Davids	william.davids@maine.edu	CIE	Co-PI

Use the table below to list all students who have participated in the project.

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
Sebastian Montoya		Master	Civil Engineering	Research Assistant

Use the table below to list any students who worked on this project and graduated during this reporting period.

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

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

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**
Maine Department of Transportation	Maine	X				

List all other outputs, outcomes, and impacts here (i.e. patent applications, technologies, techniques, licenses issued, and/or website addresses used to disseminate research findings). Please be sure to provide detailed information about each item as with the tables above.

Have other collaborators or contacts been involved? If so, who and how? (This would include collaborations with others within the lead or partner universities; especially interdepartmental or interdisciplinary collaborations.)

Table 9: Other Collaborators			
Collaborator Name and Title	**Contact Information**	**Organization and Department**	**Contribution to Research**
			(i.e. Technical Champion)

Who is the Technical Champion for this project?
Name: Laura Krusinksi
Title: Senior Geotechnical Engineer
Organization: MaineDOT
Location (City & State): August, Maine
Email Address: laura.krusinkski@maine.gov

<u>Changes:</u>

There are no changes since the previous report.

<u>Planned Activities:</u>

Description of future activities over the coming months.

As previously mentioned, strength and behavior of threaded connections under combined axial and bending load has not been studied, therefore a theoretical study will be developed based on the methodology adopted for bending strength of connections, but extended to capture the effects of axial loads. Additionally, previous analysis developed using 2D finite element software will be extended to 3D (Plaxis 3D, v2020), so that effects due to bridge skew can be introduced. Future FEA will include the analysis of rock socket behavior and methodologic study for representing threaded connections in a simple and effective way into the finite element models.