<u>Quarterly Progress Report</u>:
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: *Q2 2020*
Submission Date: *June 30, 2020*

<u>Overview:</u> (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** ….*

Preliminary 2D finite element analyses (FEA) were conducted using the commercial finite element code Plaxis 2D, version 2019. The FEA was intended to assess finite element procedures and the constitutive models adopted to simulate long-term thermal and shrinkage deformations of the bridge superstructure by comparing predictions with observations from a heavily instrumented Coplin Plantation IAB constructed in Maine (Davids et al. 2010). Prior to comparison of the entire IAB system, adequacy of the pile's 2D (plane strain) representation under lateral loading is illustrated with comparison to a full-scale pushover lateral load test performed by Frosch and Lovell (2011). Figure 1a shows the load-test configuration and pile properties for the pushover test. Figure 1b shows the IAB bridge geometry and soil layering associated with each abutment, as well as the simplified 2D geometry applied during the FEA of the IAB system. 2D Model captures the main features of the substructure behavior (pile and abutment displacements) under thermal deformations imposed by the superstructure. Although there are limitations in the 2D model due to the inner three-dimensional nature of the problem, the model results were in good agreement with measurements reported in the literature, showing similar deformed shape and order of magnitude (see Figure *1*).

To following findings from the parametric study are highlighted:

- Pile length and bedrock embedment has a negligible influence on lateral deformations, which are controlled, in large part, by the bridge span length and temperature fluctuations.
- For the same span length, stresses imposed on the pile can be appreciably influenced by the penetration depth and geologic material within which the pile is embedded. The maximum stresses were found to be mainly controlled by the bridge span length and bending stresses arising for abutment deflections and rotation were substantially greater than axial stresses imposed under the deadweight of the superstructure.
- The foundation system should provide adequate bearing capacity and achieve tolerable settlements, but pile length should be optimized to reduce stresses in the element, as developing fixity does not necessarily improve performance. Note that we have not considered other loading scenarios at this stage (e.g. collision/impact), which may otherwise dictate greater embedment is needed to generate lateral resistance provided by the foundation.

The following conclusions are draw from the 2D finite element analysis:

- 2D (plain strain) FEAs are capable of capturing the main features contributing to IAB performance and loading on the foundation system, such as deck expansion/contraction. However, 3D effects such as bridge skew, non-uniform (i.e., out-of-plane) soil conditions are neglected. In that same vein, any torsional loading on the pile is neglected.

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: Finite Element model setup	December 27th 2020	January 31st 2020	100

Task 2: Model calibration	February 1st 2020	February 15th 2020	100
Task 3: Python programming	February 16th 2020	February 21st 2020	100
Task 4: Parametric Analysis	February 22nd 2020	February 29th 2020	100
Overall Project:	*September 3rd 2019*	*May 2021*	40%

Table 2: Budget Progress		
Project Budget	**Spend – Project to Date**	**% Project to Date***

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)**
Presentation title	Name of event (i.e. TIDC 1st Annual Conference)	i.e. Conference, Symposium, Seminar,		

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)…

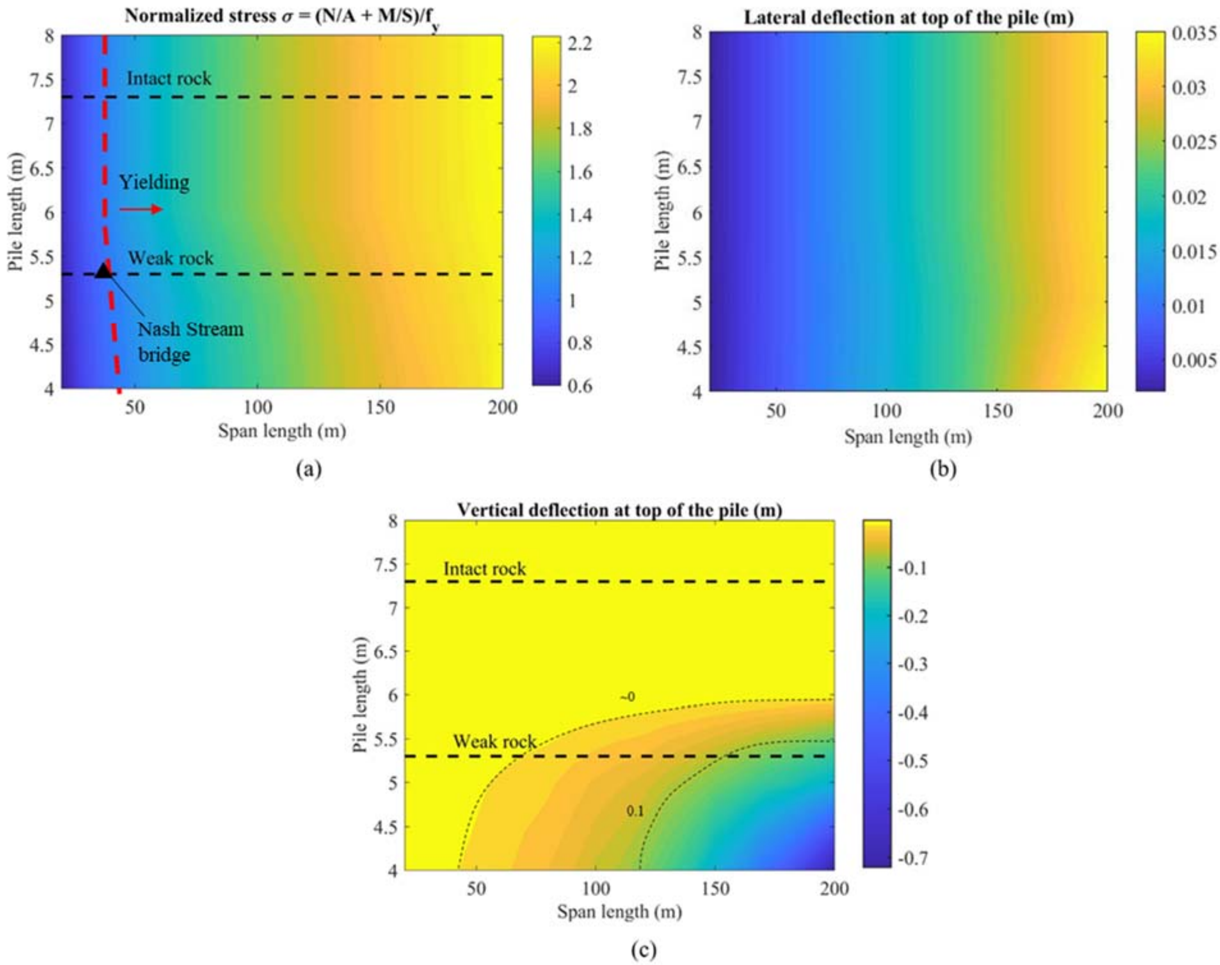

Figure 1 Parametric study: (a) normalized maximum axial stress in piles; (b) lateral deflection at the top of the pile; and (c) vertical deflection at the top of the pile

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>

The original scope of work included a monitoring program, complimented by 3D finite element (numerical) analyses, to assess the performance of an IAB micropile foundation system. Due to MaineDOT budget constraints and delayed construction of the proposed IAB, a monitoring program will no longer be conducted in what is now considered Phase I of this project.

In Phase I, 2D and 3D finite element analyses will be expanded to consider a wider range of conditions, including: bridge length; bedrock depth, strength, and stiffness; overlying soil strength and stiffness; and abutment skew angle. All analyses will consider the influence of annual temperature fluctuations and creep/shrinkage of the bridge deck associated with imposed deformations, thus combined axial, lateral, and torsional loading, on the IAB foundation system. The numerical demonstration will inform specific design guidance generated for simplified 2D p-y analyses (ubiquitous in industry) typically applied to assess IAB foundation systems. A full-scale monitoring program may be considered in the future as part of a Phase II project, which will be informed by the numerical study in Phase I.

Planned Activities:

Description of future activities over the coming months.

As previously mentioned, micropile-supported IAB allowable length will be controlled by the induced stresses on the substructure, which increase as the bridge span increases. As suggested by Razmi et al. (2013) and Salman and Issa (2019), the fatigue life of piles is strongly affected by the bridge span, as longer spans produce bigger thermal deformations and thus, more severe strain/stress cycles leading to fatigue failure. In view of this, small induced-to-yield stress ratios (σ/σ_y) or the equivalent strain ratio (ϵ/ϵ_y) are desirable to decrease the fatigue of the piles. According to Quinn and Civjan (2017), maximum-to-yield bending moment ratio (M/M_y) in H-piles reduces when the piles are oriented with the weak axis normal to the abutment, i.e., smaller σ/σ_y or ϵ/ϵ_y. Thus, H-piles under the weak axis configuration allow longer IABs to be constructed. Similar considerations will be given to micropiles. Future work will incorporate 3D finite element analyses to assess 3D effects previously discussed.

The ultimate objective will be to provide specific design guidance on acceptable bridge dimensions associated with this foundation type.

References

Davids, W.G., Sandford, T., Ashley (neé Hartt), S., DeLano, J., Lyons, C., 2010. Field-Measured Response of an Integral Abutment Bridge with Short Steel H-Piles. J. Bridg. Eng. 15, 32–43. https://doi.org/10.1061/(ASCE)1084-0702(2010)15:1(32)

Frosch, R.J., Lovell, M.D., 2011. Long-Term Behavior of Integral Abutment Bridges. https://doi.org/10.5703/1288284314640

Kulhawy, F.H., Mayne, P.W., 1990. Manual of Estimating Soil Properties for Foundation Design. Ithaca.

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