**Quarterly Progress Report:**
**Project Number and Title:** 3.12—Lateral Loading of Unreinforced Rigid Elements and Basal Stability of Column-supported Systems
**Research Area:** Geotechnical Infrastructure Engineering
**PI:** *Aaron Gallant, University of Maine*
**Co-PI(s):**
**Reporting Period:** *04/2019-06/2019*
**Submission Date:** *6/30/2020*

**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** ….*

In this quarterly report, the basal stability of embankments supported on rigid columns over soft soil was investigated. The goal of the project is to understand the two types of systems (i.e. embankments and Mechanically Stabilized Earth MSE wall). The emphasis was given to the embankment loading type. A detailed review of field observations from case histories was carried out to: i.) illustrate the conditions- including column configuration, and subsoil profile- governing the distribution of lateral deformation in the foundation soils at depth as an indicator of their typical performance, ii.) determine the variables and their intervals for the parametric study based on typical column configurations and subsoil conditions reported in the cases histories, and iii.) compare the observed lateral deformations in the case histories with the computed ones in the numerical analysis to provide context. Each field case was classified into two categories: column type (high- and low-modulus) and penetration length through a soft soil layer (floating—FT, full penetration—FP, or embedment in a bearing layer—EB). The surficial layer was divided into "loose" or "dense", depending of its stiffness and overconsolidation ratio (OCR). A numerical 3D finite element study was conducted to examine the influence of column fracturing on the performance of hypothetical column supported embankments (CSE). Observations for the inventory case histories were compared with the computed deformations to provide context regarding the predicted performance of CSEs supported on fractured columns.

The most important findings of this report are:

- Based on the observed distribution of the lateral deformation in the field cases, the surficial layer plays an important role in the basal stability and lateral spreading of the system. When a stiffer/stronger surficial layer was present, the maximum deformation was typically below or near to the bottom of this layer, and when a softer/weaker surficial layer exists, the maximum lateral deformation was found at the top or near to the ground surface. Typical maximum normalized lateral deformation with fill height observed near to the toe of the CSE is less than 1% for low modulus column and 0.6% for high modulus column.
- For the numerical analysis, comparison on the response of a fractured (i.e. zero bending resistance) and infinite bending stiffness column was made for a typical case studied (height fill equal to 5 m, column spacing equal 2 m, column diameter 0.5 m, thickness of the surficial layer 1.5 m, slope H=1.5:V=1, and the thickness of the soft clay equal to 8.5 m) concluding that bending capacity had no appreciable influence on the vertical load transfer or computed lateral deformation.
- The results of the parametric study highlighted the effect of crust thickness on lateral spreading. As the crust thickness increases, the lateral deformation decreases for the same subsoil, drainage, and column conditions. This result demonstrates that the characterization (strength, stiffness, and thickness) of the surficial layer plays a key role in the CSE designs (see Figure 1). This was also demonstrated with the field cases where higher replacement area ratio was related with loose surficial layers.

| Table 1: Task Progress | | | |
|---|---|---|---|
| **Task Number** | **Start Date** | **End Date** | **% Complete** |
| Task 1: Assess stresses in subsoil. | 06/2018 | 06/2019 | 100% |
| Task 2: Establish a numerical approach to account for fracture in basal stability. | 06/2019 | 09/2019 | 100% |
| Task 3: Calibrate models with field measurements that include lateral and vertical deformations. | 06/2019 | 01/2020 | 100% |
| Task 4: Perform parametric study for fill embankments. | 01/2020 | 04/2020 | 100% |
| Task 5: Perform parametric study for MSE walls. | 06/2020 | 07/2020 | 10% |
| Task 6: Recommended design guidance for industry. | 03/2020 | 05/2020 | 30% |
| Overall Project: | 06/2018 | 05/2020 | 75% |

| Table 2: Budget Progress | | |
|---|---|---|
| **Project Budget** | **Spend – Project to Date** | **% Project to Date*** |
| $33,380 | $25,000 | |

***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)** |
| N/A | | | | |

| Table 4: Publications and Submitted Papers and Reports | | | | |
|---|---|---|---|---|
| **Type** | **Title** | **Citation** | **Date** | **Status** |
| Journal | Field Observations and Analysis of the Subgrade Response beneath GRCS Embankments at the Council Bluffs Interchange System | Gallant, Aaron, Ehab Shatnawi, and Danilo Botero-Lopez. 2019. "Field Observations and Analysis of the Subgrade Response beneath GRCS Embankments at the Council Bluffs Interchange System." Journal of Geotechnical and Geoenviromental Engineering. | 2020 | Accepted |

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

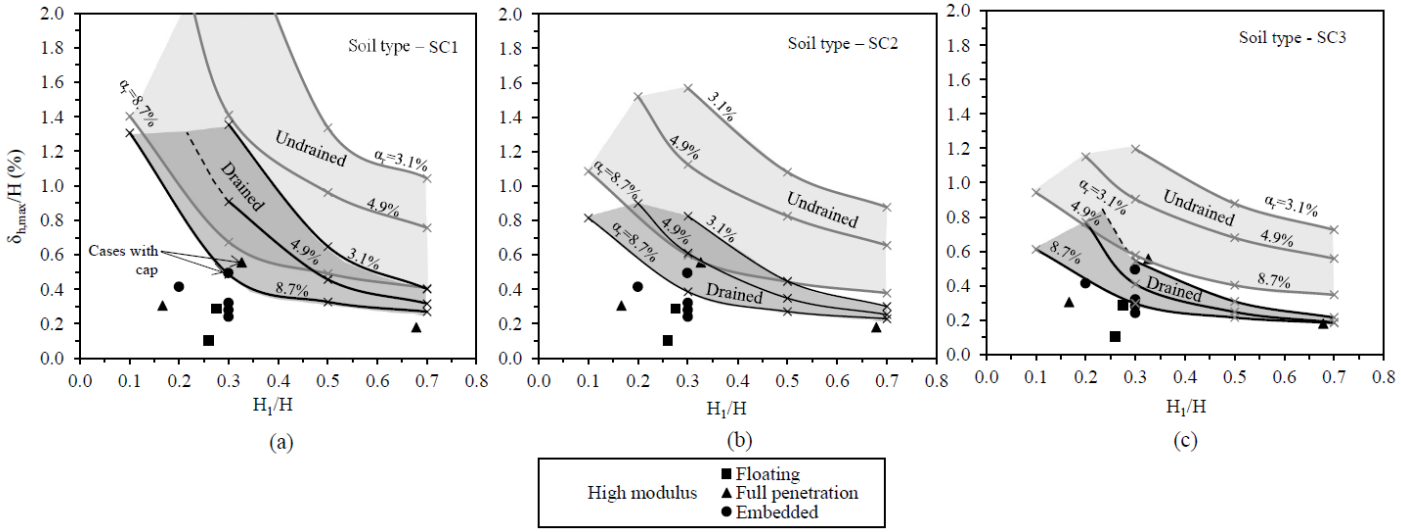


**Figure 1.** Computed maximum normalized lateral deformations at one spacing from toe vs. normalized stiff surficial layer thickness with fill height for three types of soft soils (a) Softer clay, (b) Soft clay and, (c) stiffer clay. Comparison is made with case history data for all high modulus columns.

**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 | Civil | PI |

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

| Table 6: Student Participants during the reporting period | | | | |
|---|---|---|---|---|
| **Student Name** | **Email Address** | **Class** | **Major** | **Role in research** |
| Danilo Botero-Lopez | | 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** |
| N/A | | | |

*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** |
| Deep Foundations Institute (DFI) | Hawthorne, NJ | X | | | | |
| Jacobs Engineering | Herndon, VA | | 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 |
|---|---|---|---|
| N/A | | | |

*Who is the Technical Champion for this project?*
Name: Tanner Balckburn
Title: Chief Geotechnical Engineering
Organization: Hayward Baker
Location (City & State):
Email Address: jtblackburn@keller-na.com

**Changes:**
N/A

**Planned Activities:**

Future work will be focused on the parametric study for column supported MSE walls to facilitate creation of design guidelines regarding lateral spread and basal stability of these systems.