Quarterly Progress Report:
Project Number and Title: 2.9: Carbonating Subgrade Materials for In-Situ Soil Stabilization
Research Area: New Materials for Longevity and constructability
PI: Aaron Gallant, Ph.D., P.E., University of Maine
Co-PI(s): Warda Ashraf, Ph.D., University of Texas at Arlington
Reporting Period: 10/1/2020-12/31/2020
Submission Date: 12/31/2020

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** ….*

Previously we have reported that the effects of initial water contents on degree of carbonation and rapid strength improvement of lime (10% by weight) mixed sand via accelerated carbonation at low CO_2 pressure. We also looked at the effects on initial dry density, γ_d (or void ratio, e) on binder formation rate and associated soil strength. Results revealed that the maximum calcium carbonate binder formation in terms of degree of carbonation was as high as around 85% in 120 hours of carbonation with unconfined compressive strength of 3 MPa. However, the carbonated soil strength was reduced significantly (by more than 60%) when the dry density is decreased from 17.4 kN/m^3 (e 0.48) to 15.7 kN/m^3 (e 0.64) although they had similar degree of carbonation (i.e. 90% approximately) after 168 hours of carbonation. Following this, we also investigated the effects of aforesaid soil state parameters on soil carbonation for wide range of soils. In this report, we present the results of 10% lime mixed silt that were prepared at varying water contents and densities, and carbonated for different time periods. The mechanical (strength) improvement and carbonate binder formation (degree of carbonation) were tested through unconfined compressive strength (UCS) and thermogravimetric analyses (TGA). As such, we have performed a total of 48 nos. of UCS tests and 32 nos. of TGA tests to understand the state dependency of carbonated strength of silts. Additional tests considering varying fine contents (i.e. soil type) have been completed and the full findings will be presented in the next report.

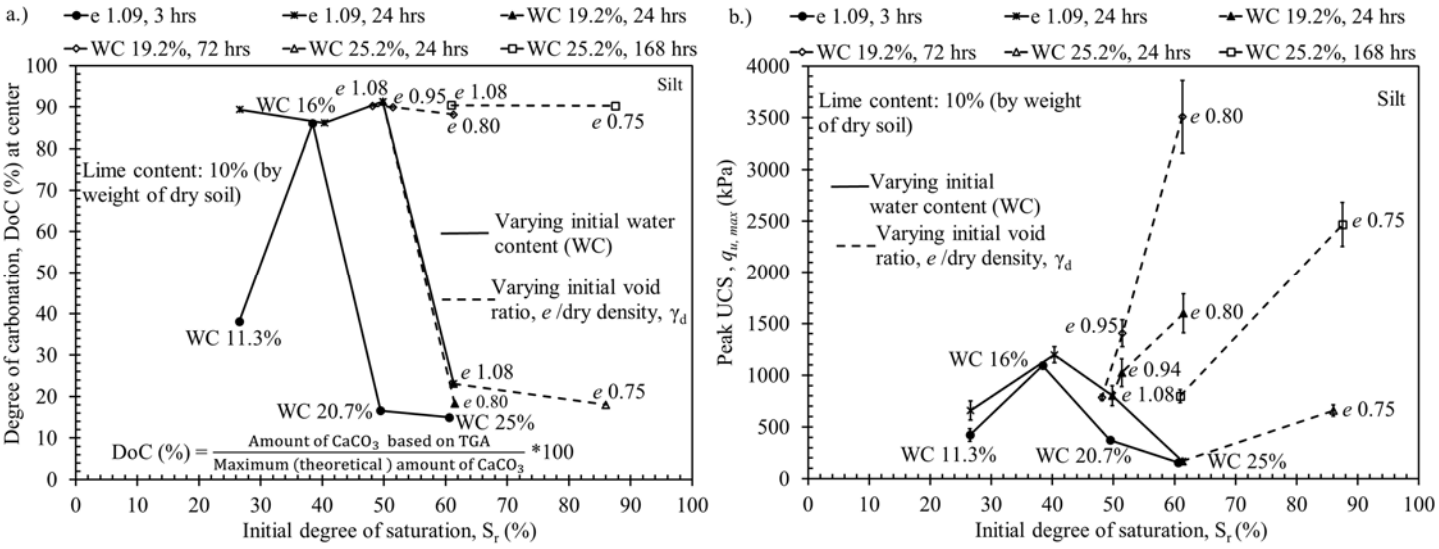

Figure 1. Effects of initial water content and void ratio (dry density) on a.) degree of carbonation, b.) carbonated soil strength of lime-mixed silt

Figure 1 shows the degree of carbonation and unconfined compressive strength (UCS) versus initial degree of saturation, S_r of lime (10% by weight) mixed silt specimens that were prepared at varying water contents and densities. The specimens were carbonated between 3-168 hours. Results revealed that rate of carbonation is strongly correlated with initial degree of

saturation and silt can achieve maximum degree of carbonation (S_r) as high as 90% in 24-72 hours when the S_r is between 40-55%. However, S_r higher than 55% significantly increased the carbonation time (e.g. 168 hours) due to lower mobility CO_2 gas to achieve maximum carbonation. In terms of strength, maximum UCS is observed when the void ratio is reduced (i.e. density is increased) and have maximum binder formation (i.e. maximum carbonation). Like sand, silt also obtained maximum UCS of 3.5 MPa when the initial WC and γ_d were 19% and 14.3 kN/m^3, respectively. The optimum strength of carbonated soils is attributed to maximum carbonation and more compacted soil structure.

Provide context as to how these activities are helping achieve the overarching goal(s) of the project…

Elemental testing of Phase I of the project is being performed to characterize the factors contributing to soil carbonation and its application on different soil types to gain rapid strength. It would also provide a framework on designing large scale laboratory testing and field trial for optimum conditions to stabilize soils via carbonation and obtain target strength in the field.

Describe any accomplishments achieved under the project goals…

One peer-reviewed conference paper has been published in Geo-Congress 2020: Foundations, Soil Improvement, and Erosion under Geotechnical Special Publication No. 315, Geo-Institute (G-I) of the American Society of Civil Engineers (ASCE). Additionally, a total of three poster presentations have been made to date in various platforms including 2019 UMaine Student Symposium, Geo-Congress 2020 (held in Minneapolis, MN) and 2020 TIDC Student Poster Competition (October 2020).

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: Literature Review	September 2018	Ongoing	100% to date
Task 2: Elemental testing	December 2018	December 2020	100%
Task 3: Pseudo Field-Scale Trial (Laboratory soil box)	February 2021	August 2021	0%
Overall Project:	September 2018	August 2021	55%

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…

N/A

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)
Soil State Dependency of Carbonation for Rapid Strength Improvement	2020 TIDC Student Poster Contest	Student poster competition	Virtual	10/21/2020

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
Peer-reviewed conference paper	Elemental testing of carbonated silty sand treated with lime	Hossen, S. B., Gallant, A. P., & Ashraf, W. (2020). Elemental Testing of Carbonated Silty Sand Treated with Lime. *Geo-Congress 2020*, ASCE GSP 315, Minneapolis MN, pp. 562-571.	February 21, 2020	Published
Peer-review Journal	Influence of initial soil state parameters on rapid strength gain of granular soils under low CO_2 pressure conditions	Hossen, S. B., Gallant, A. P., & Ashraf, W. (2021). Influence of initial soil state parameters on rapid strength gain of granular soils under low CO_2 pressure conditions. *Can. Geotech. J.*, (In preparation).	-	Under in-house review for final submission

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, PhD, PE	aaron.gallant@maine.edu	Civil Engineering, University of Maine	PI
Warda Ashraf, PhD	warda.ashraf@uta.edu	Civil Engineering, UT Arlington	Co-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**
SK Belal Hossen, EI		PhD	Civil and geotechnical engineering	Graduate Research Assistant

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

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. **N/A**

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**

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. **N/A**

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.) **N/A**

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: Dale Peabody
Title: Director of Transportation Research
Organization: Maine DOT
Location (City & State): Augusta, ME
Email Address: dale.peabody@maine.gov

Changes:

Discuss any actual or anticipated problems or delays and actions or plans to resolve them…
Discuss any changes in approach and the reasons for the change…
N/A

Planned Activities:

Description of future activities over the coming months.
We plan to explore the potential use of industry by-product *Ground Granulated Blast Furnace Slag (GGBFS)* as an alternative alkaline source (apart from lime) to make soil carbonation more sustainable and cost-effective ground improvement method. In such, we will perform an exclusive test series based on our knowledge and understanding from the elemental testing/results performed this year. In parallel, we will review literature to design the soil carbonation box and get involved with external experts to build it in our composite center on campus to demonstrate large scale implementation of soil carbonation technology.