Quarterly Progress and Performance Indicators Report:
Project Number and Title: 3.13: Investigating the Effectiveness of Enzymatic Stabilizers for Reclaimed Stabilized Base Projects
Research Area: Thrust # 3, New systems for longevity and constructability
PI: *Ehsan Ghazanfari, The University of Vermont*
Co-PI(s): *Mandar Dewoolkar, The University of Vermont*
Reporting Period: *1/1/2022 to 3/31/2022*
Submission Date: *3/31/2022*

Overview:

The overarching goal of this project is to evaluate the effectiveness of enzymatic stabilizers in RSB projects in Vermont and the NE region. During the past quarter, we continued working with Xanthan Gum as a potential stabilizer and performed preliminary experiments on specimens treated with microbially induced calcite precipitation. For Xanthan Gum (XG), a review of the previous test data and discussions on the field applicability of the material as a road base binder has identified the need for permeability metrics. Previous attempts at measuring permeability using water were not successful due to the hydrophilic nature of XG. Other alternatives for estimation of permeability were explored and sample preparations for permeability testing are under way. Preliminary tests with microbially induced calcite precipitation (MICP) have been conducted. MICP has shown promise as an environmentally conscious method of leveraging the biological component of soil to produce calcite in-situ and strengthen the soil. Preliminary tests in the laboratory have focused on optimizing bacteria and cementation solution chemistry, sample preparation, and injection methods. Preliminary tests have been successful in producing calcite and cementing the test materials. We are continuing laboratory testing using different stabilizers and various gradations to better understand the mechanism of strength improvement and assess the effectiveness of the stabilizers. The performed work in previous months helps us move closer toward the next steps of the project in evaluating the effectiveness of the enzymatic stabilizers in RSB projects and determining the appropriate enzymatic agent for the type of base/subbase material encountered in different RSB projects.

Task, Milestone, and Budget Progress:

Table 1: Task Progress

Task Number: Title	Start Date	End Date	% Complete
Task 1: Prepare specimens with enzymatic stabilizing agents	1/1/2021	11/1/2021	40%
Task 2: Evaluate the strength and stiffness improvement and hydraulic response of prepared specimens	1/1/2021	3/31/2022	35%
Task 3: Investigate the mechanism of strength improvement and develop design parameters	2/1/2022	8/31/2022	35%

Task 4: Perform relatively large-scale laboratory tests and/or field tests to evaluate the performance of enzymatic stabilizers	9/1/2022	8/1/2023	0%
Task 5: Provide a set of recommendations and develop guidelines for implementation	1/1/2023	8/31/2023	0%
Overall Project	*1/1/2021*	*8/31/2023*	35%

Table 2: Milestone Progress

Milestone #: Description	Corresponding Deliverable	Start Date	End Date
Prepare specimens with enzymatic stabilizing agents	Report/presentation to TAC	9/1/2020	1/31/2021
Prepare and cure specimens with various enzymatic stabilizing agents and various percentages	Report/presentation to TAC and TIDC	2/1/2021	11/1/2021
Evaluate the strength-gain (UCS) of prepared specimens	Report/presentation to TAC and TIDC	1/1/2021	7/31/2021
Evaluate the UCS, shear strength, stiffness and permeability of specimens with various enzymatic stabilizing agents and various percentages	Report/presentation to TAC, TIDC, semi-annual report supplement	8/1/2021	3/31/2022
Investigate the mechanism of strength improvement in stabilized specimens	Report/presentation to TAC, TIDC	2/1/2022	5/31/2022
Develop design parameters for enzymatic stabilization	Report/presentation to TAC, TIDC, semi-annual report supplement	6/1/2020	8/31/2022
Perform large-scale laboratory and field tests to evaluate the performance of enzymatic stabilizers	Report/presentation to TAC, TIDC	9/1/2022	8/1/2023
Provide a set of recommendations and develop guidelines for implementation	Report/presentation to TAC, TIDC, semi-annual report supplement	1/1/2023	8/31/2023

Table 3: Budget Progress

Project Budget	Spend – Project to Date	% Project to Date (include the date)
$538,278	$184,210	34.2%

Is your Research Project Applied or Advanced?

☒ **Applied** (*The systematic study to gain knowledge or understanding necessary for determining the means by which a recognized and specific need may be met.)*

☐ **Advanced** *(An intermediate research effort between basic research and applied research. This study bridges basic (study to understand fundamental aspects of phenomena without specific applications in mind) and applied research and includes transformative change rather than incremental advances. The investigation into the use of basic research results to an area of application without a specific problem to resolve.)*

Education and Workforce Development:

Answer the following questions (N/A if there is nothing to report):

1. Did you provide any workforce development or training opportunities to transportation professionals (already in the field)? If so, what was the training? When was it offered? How many people attended?

   No

2. Did you hold meetings with any transportation industry organizations or DOTs? If so, what was the meeting's purpose? When was it offered? How many people attended?

   No

3. Did you host/participant in any K-12 education outreach activities? If so, what was the activity? What was the target age/grade level of the participants? How many students/teachers attended? When was the activity held?

   No

Technology Transfer:

Table 4: Presentations at Conferences, Workshops, Seminars, and Other Events					
Type	**Title**	**Citation**	**Event & Intended Audience**	**Location**	**Date(s)**
i.e. Conference, Symposium, DOT/AOT presentation, Seminar, etc.	Presentation Title	Full Citation	Name of event (i.e. TIDC 1st Annual Conference) or who was the presentation given to?		
N/A	N/A	N/A	N/A	N/A	N/A

Table 5: Submitted/Accepted Publications, Technical Reports, Theses, Dissertations, Papers, and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
i.e. Peer-reviewed journal, conference paper, book, policy paper, magazine/newspaper article	Publication title	Full citation		i.e. Submitted, accepted, under review (by org. submitted to)
N/A	N/A	N/A	N/A	N/A

Answer the following questions (N/A if there is nothing to report):

1. Did you deploy any technology during the reporting period through pilot or demonstration studies as a result of this work? If so, what was the technology? When was it deployed?
   No

2. Was any technology adopted by industry or transportation agencies as a result of this work? If so, what was the technology? When was is adopted? Who adopted the technology?
   No

3. Did findings from this research project result in changing industry or transportation agency practices, decision making, or policies? If so, what was the change? When was the change implemented? Who adopted the change?
   N/A

4. Were any licenses granted to industry as a result of findings from this work? If so, when? To whom was the license granted?
   No

5. Were any patent applications submitted as a result of findings from this research? If so, please provide a copy of the patent application with your report.
   No

6. Did industry organizations or DOTs provide cost-share (cash or in-kind) to your research during the reporting period? Who was the organization? Please provide an in-kind support invoice from the organization with your report (this is kept confidential and used for record keeping purposes only).
   Yes, Vermont Agency of Transportation

Outputs:

Research is ongoing.

Outcomes:

Research is ongoing.

Impacts:

Research is ongoing

Participants and Collaborators:

Table 6: Active Principal Investigators, faculty, administrators, and Management Team Members				
Individual Name & Title	**Dates involved**	**Email Address**	**Department**	**Role in Research**
Ehsan Ghazanfari	1/1/2021-present	Ehsan.ghazanfari@uvm.edu	Civil & Environmental Engineering	Principal Investigator
Mandar Dewoolkar	1/1/2021-present	Mandar.Dewoolkar@uvm.edu	Civil & Environmental Engineering	Co-Principal Investigator

Table 7: Student Participants during the reporting period								
Student Name	**Start Date**	**End Date**	**Advisor**	**Email Address**	**Level**	**Major**	**Funding Source**	**Role in research**
Ryan van der Heijden	1/9/2021	Cont.	Ghazanfari and Dewoolkar		Ph.D.	Civil & Environmental Engineering	TIDC	Graduate Research Assistant

Table 8: Students who Graduated During the Reporting Period			
Student Name	**Degree/Certificate Earned**	**Graduation/Certification Date**	**Did the student enter the transportation field or continue another degree at your university?**
N/A	N/A	N/A	N/A

Table 9: Industrial Internships			
Student Name	**Degree/Certificate Earned**	**Graduation/Certification Date**	**Did the student enter the transportation field or continue another degree at your university?**
N/A	N/A	N/A	N/A

Table 10: Research Project Collaborators during the reporting period						
Organization	**Location**	**Contribution to the Project**				
		Financial Support	**In-Kind Support**	**Facilities**	**Collaborative Research**	**Personnel Exchanges**
N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 11: Other Collaborators				
Collaborator Name and Title	**Contact Information**	**Organization and Department**	**Date(s) Involved**	**Contribution to Research**
Callie Ewald, Geotechnical Engineering Manager		Vermont Agency of Transportation	1/1/2021-present	Technical Advisory Committee Chair

Table 12: Course List						
Course Code	**Course Title**	**Level**	**University**	**Professor**	**Semester**	**# of Students**
N/A	N/A	N/A	N/A	N/A	N/A	N/A

Changes:
None

Planned Activities:
continue preparing, curing, and testing sub-base soil specimens stabilized with enzymatic stabilizing agents