**TRANSPORTATION POOLED FUND PROGRAM**

**QUARTERLY PROGRESS REPORT**

**Lead Agency: Utah Department of Transportation**

**INSTRUCTIONS:**

*Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.*

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| **Transportation Pooled Fund Program Project #****TPF-5(433)** | **Transportation Pooled Fund Program - Report Period:** \_ Quarter 1 (January 1 – March 31, 2022)\_ Quarter 2 (April 1 – June 30, 2022)\_ Quarter 3 (July 1 – September 30, 2022)**x Quarter 4 (October 1 – December 31, 2022)** |
| **Project Title:**Behavior of Reinforced and Unreinforced Lightweight Cellular Concrete for Retaining Walls |
| **Name of Project Manager(s):**David Stevens | **Phone Number:** 801-589-8340 | **E-Mail** davidstevens@utah.gov |
| **Lead Agency Project ID:**FINET 42096, ePM PIN 17824UDOT PIC No. UT18.404 | **Other Project ID (i.e., contract #):** UDOT Contract No. 20-9367  | **Project Start Date:** May 21, 2020 (contract) |
| **Original Project End Date:**September 30, 2022 (scope) | **Current Project End Date:** September 30, 2023 (scope) | **Number of Extensions:**2 |

Project schedule status:

 \_ On schedule **X** On revised schedule \_ Ahead of schedule \_ Behind schedule

Overall Project Statistics:

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|  **Total Project Budget** |  **Total Cost to Date for Project** |  **Percentage of Work**  **Completed to Date** |
| Total commitments = $337,500.00Obligated to date = $337,500.00(incl. $7,500 state match on FHWA contrib.)Contract amount = $325,578.00Remaining on contract = $139,258.00 | Contract spent = $186,320.00Contract support = $428.01Total spent = $186,748.01 | 70% |

***Quarterly*** Project Statistics (on this contract):

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|  **Total Project Expenses**  **and Percentage This Quarter** |  **Total Amount of Funds**  **Expended This Quarter** |  **Total Percentage of**  **Time Used to Date** |
| 0% | $0.00 | 78% |

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| **Project Description**:Roadway widening over existing walls and embankments, conflicts with settlement-sensitive utilities, and accelerated schedule delivery have increased demands for alternative lightweight fill materials. Engineers and contractors are increasingly considering Lightweight Cellular Concrete (LCC) backfills for abutments, embankments, and Mechanically Stabilized Earth (MSE) retaining walls; however, the absence of a consistent design methodology has led to a wide range of design approaches with no consensus standard. The most common class of LCC used in previous highway projects does not strictly behave like a soil or like concrete and must be investigated as a new material for engineering applications. Controversy exists within the industry regarding whether LCC should be modeled as a frictional or a cementitious (cohesive) material. In addition, earth pressures for retaining wall design and potential failure mechanisms of LCC are poorly understood for retaining wall applications, including uncertainty in LCC interaction with internal wall reinforcement in MSE wall applications.Objective: Measure engineering design parameters and failure mechanisms for unreinforced and reinforced LCC backfills based on large-scale laboratory tests.Funded tasks for this study include the following: 1. Literature review and survey2. Basic material properties lab testing 3. Unreinforced LCC large-scale testing4. Reinforced LCC large-scale testing:* Reinforced LCC Test 1 – MSE wall with LCC backfill,
* Reinforced LCC Test 2 – MSE wall with LCC backfill against soil slope,
* Reinforced LCC Test 3 – MSE wall test with lower strength LCC backfill,
* Reinforced LCC Test 4 – Pull-out tests on MSE wall, and
* Reinforced LCC Test 5 – MSE wall test with welded-wire reinforcement

5. Compare results with design methods6. Final Reports for (a) the unreinforced LCC test and (b) the reinforced LCC tests7. Meetings and dissemination of resultsThe Principal Investigators for this study are Dr. Kyle Rollins of Brigham Young University and Ryan Maw, a principal engineer at Gerhart-Cole, Inc. The technical advisory committee (TAC) for the study currently includes representatives from UT, CA, KS, LA, MI, NY, OR, and WA state DOTs and FHWA. TAC meetings will be held periodically during the study and are currently planned to be web conferences. |

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| **Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):****Task 1** – 50% complete. Continued the literature review and survey.**Task 2** – 100% complete.**Task 3** – 100% complete.**Task 4** – 100% complete.**Task 5** – 40% complete. Continued work on Detailed Interim Reports including key parameters from the reinforced tests. Design comparison was found to be challenging. TAC reviewed the interim report on the first MSE LCC test.**Task 6** – 50% complete. TAC reviewed the Draft Final Report for the unreinforced LCC test.**Task 7** – 50% complete. No TAC meetings were held this quarter.**Contract** – No changes were made. |
| **Anticipated work next quarter**:**Task 1** – Continue the literature review and survey.**Task 2** – Completed.**Task 3** – Completed.**Task 4** – Completed.**Task 5** – Continue work on Detailed Interim Reports including key parameters from the reinforced tests. Address TAC comments in the updated interim report on the first MSE LCC test.**Task 6** – Address TAC comments in the updated Final Report for the unreinforced LCC test. Work on the Draft Final Report for the reinforced LCC tests.**Task 7** – Consider holding another TAC update meeting (virtual) after more reports are completed.**Contract** – No changes to the contract are planned. |

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| **Significant Results:**Additional study reports are being prepared for TAC review. The plan and status for the study reports are shown below:* **Short Interim Reports: (to post final on TPF website; BYU’s format; UDOT won’t publish)**
	+ Unreinforced LCC testing (posted on TPF website)
	+ Reinforced LCC Test 1 – MSE wall with LCC backfill (posted on TPF website)
	+ Reinforced LCC Test 2 – MSE wall with LCC backfill against soil slope (posted on TPF website)
	+ Reinforced LCC Test 3 – MSE wall test with lower strength LCC backfill (posted on TPF website)
	+ Reinforced LCC Test 4 – Pull-out tests on MSE wall (posted on TPF website)
	+ Reinforced LCC Test 5 – MSE wall test with welded-wire reinforcement (posted on TPF website)
* **Detailed Interim Reports: (to post final on TPF website; BYU’s format; UDOT won't publish)**
	+ 1st MSE LCC test (draft received and in TAC review)
	+ Pull-out resistance (draft almost ready)
	+ Slope stability (draft almost ready)
	+ Lower strength MSE LCC test (draft ready in 2-3 months)
	+ Sliver fill MSE LCC test (draft ready in 2-3 months)
	+ Welded wire reinforcement (draft ready in 2-3 months)
* **Short Report: (to post final on TPF website; BYU’s format; UDOT won't publish)**
	+ Pile lateral analysis in MSE LCC
* **Final Reports: (to post final on TPF website; UDOT’s format; UDOT will publish)**
	+ Unreinforced LCC RCC tests (draft received and in TAC review)
	+ Reinforced LCC tests (Lit. review, summary of all reinforced tests, comparison of all tests, pull-out resistance, and slope stability) (draft ready in 3 to 6 months)

During this quarter, the research team has been working to calibrate the pull-out resistance of the reinforcements at the high pressures during surcharge failure of the reinforced LCC using slope stability techniques. Our pull-out test data set currently has tests with a maximum vertical pressure of 1400 to 1800 psf on the reinforcements (46 to 60 ft of LCC self-weight). In contrast, the maximum pressure during failure of the reinforced LCC in the large box was five times this value (about 9500 psf). To obtain a factor of safety of 1.0 in the slope stability model when the surcharge pressure is equal to that in the box, we are finding that the F\* value must be reduced relative to that for a pressure of 1400 psf. A plot of the F\*(ST/t) versus depth curve that fits both the pull-out test results and the back-calculated value obtained based on surcharge failure is provided in Fig. 1. For the welded-wire reinforcement in this case, the F\*(ST/t) value must continue to decrease with increasing pressure rather than remaining constant with depth as is the case for sand and gravel backfill around an MSE reinforcement. However, the required reduction in F\* does not seem unreasonable relative to the original pull-out tests (see Fig. 1a) and may represent a simple solution to the problem of defining F\* vs. pressure at higher pressure values (see Fig. 1b). Although the results in Fig. 1 are only for the tests with welded-wire reinforcement, we are seeing similar reductions in F\* for the large box tests with ribbed-strip reinforcements. To confirm the validity of these back-calculated F\* values, we have arranged to perform an additional set of pull-out tests on 4 welded wire reinforcements and 4 ribbed strip reinforcements at high vertical pressures (around 9500 psf) similar to what we had in the 10’x10’x13 ft test box. Cell-Crete Inc. will once again provide the LCC for the test boxes so that the results should be consistent with what we did previously. These tests are scheduled for early March. (b)(a)**Fig. 1 Plots of F\*(St/t) vs. depth for (a) pressure from 0 to 1600 psf based on welded-wire pull-out tests and (b) for pressure from 0 to 10,000 psf with measured pull-out test data and back-calculated pull-out resistance from slope stability models.**We are also going to use another slope stability program to confirm that we obtain back-calculated F\* values similar to what we obtained with the computer program UTexas4. Finally, we are investigating the possibility that the pull-out resistance for LCC is a combination of cohesive and frictional resistance. This approach seems to be more consistent with observed behavior of the LCC but would be more complicated for a designer to execute. |
| **Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that** **might affect the completion of the project within the time, scope and fiscal constraints set forth in the****agreement, along with recommended solutions to those problems).**No delays at this time. Testing and analysis for this research has been allowed to continue at BYU with additional health precautions related to COVID-19. |

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| **Potential Implementation:** None yet. |