**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:** **x Quarter 1 (January 1 – March 31, 2021)** \_ Quarter 2 (April 1 – June 30, 2021)\_ Quarter 3 (July 1 – September 30, 2021)\_ Quarter 4 (October 1 – December 31, 2021) |
| **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 | **Current Project End Date:** September 30, 2022 | **Number of Extensions:**1 |

Project schedule status:

 **X** On schedule \_ 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 = $227,815.00 | Contract spent = $97,763.00Contract support = $369.01Total spent = $98,132.01 | 35% |

***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** |
| 18% | $58,638.00 | 38% |

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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. Started the literature review and prepared a survey.**Task 2** – 90% complete. The BYU research team completed LCC material properties lab testing for Reinforced LCC Tests 4 and 5.**Task 3** – 100% complete.**Task 4** – 90% complete. Completed large-scale testing for Reinforced LCC Tests 4 and 5. Worked on interim reports for these tests.**Task 5** –10% complete. Started on interim reports on key parameters from the unreinforced test and the reinforced tests.**Task 6** – Not started.**Task 7** – No TAC meetings were held this quarter.**Contract** – Modified the contract to include additional scope and funding for additional large-scale testing, based on input from the TAC members. These changes include the Reinforced LCC Test 3 replacement (lower strength LCC backfill), Test 4 modification to include welded-wire reinforcements, and Test 5 addition. Funding comes from a portion of the committed and transferred pooled funding that is not yet on contract. |
| **Anticipated work next quarter**:**Task 1** – Continue the literature review and survey.**Task 2** – Completed.**Task 3** – Completed.**Task 4** – Prepare and submit interim reports with preliminary results from the Test 3 (lower strength LCC backfill), Test 4, and Test 5.**Task 5** – Start this task.**Task 6** – None.**Task 7** – Schedule and hold a TAC web conference to discuss the most recent testing results.**Contract** – No changes are planned. |

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| **Significant Results:**In the 1st quarter of 2021, the research team completed two additional tests involving LCC backfill. This effort completed a total of six LCC backfill tests In accordance with the revised contract with the Utah Dept. of Transportation. One of these tests involved MSE wall panels and LCC backfill with welded-wire reinforcements. The second test involved reinforcement pull-out tests. A total of 12 pull-out tests were performed on ribbed-strip reinforcements with variable applied surcharge pressures to evaluate the influence of vertical stress on pull-out resistance. In addition,12 pull-out tests were performed on welded-wire reinforcements on the opposite face at various surcharge pressures.Fig. 1 shows a comparison of the surcharge pressure vs. axial displacement curves for the MSE LCC tests with ribbed strip and welded-wire reinforcements. The reinforcements were designed to provide comparable pull-out resistance assuming that the backfill was sand. The two curves were very similar until they approached failure at a displacement of about 1 inch or an average axial strain of about 1%. Beyond this strain level, the LCC backfill with the welded-wire reinforcement experienced less displacement than the LCC backfill with ribbed strip reinforcements. The exact reason for this difference is not entirely known, but in the pull-out testing, we observed that the ribbed strip reinforcements exhibited strain softening after the peak value, while the pull-out resistance for the welded-wire reinforcements showed a gradual increase with displacement. This could explain why surcharge pressure deceased and axial displacement increased with displacement for the LCC with ribbed strip reinforcements.**Fig. 1 Comparison of axial displacement vs. surcharge pressure for MSE LCC tests with ribbed strip and welded-wire reinforcements.**Fig. 2 shows a comparison of the surcharge pressure vs. lateral displacement curves for the MSE LCC tests with ribbed strip and welded-wire reinforcements. Once again, the two curves were very similar until they approached failure at a displacement of about 0.5 inch. Beyond this displacement, the LCC backfill with the welded-wire reinforcement experienced less lateral displacement than the LCC backfill with ribbed strip reinforcements. As a result of this behavior, there was also less surface cracking in the LCC backfill.**Fig. 2 Comparison of lateral displacement vs. surcharge pressure for MSE LCC tests with ribbed strip and welded-wire reinforcements.**Fig. 3 provides MSE wall deflection profiles for the welded-wire and ribbed strip reinforcement surcharge tests. Both reinforcement systems kept wall displacements to below about 0.3 inch for surcharges pressure up to 55 psi. The welded-wire test yielded deflections that were consistently higher at the top; whereas, the ribbed strip test ultimately deflection more at the joint between the two panels at the highest surcharge pressure of 69 psi.(b)(a)**Fig. 3. Horizontal MSE wall deflection profiles for (a) welded-wire reinforcement and (b) ribbed strip reinforcement tests.** It is unclear if the large difference in the ultimate deflection profiles is a result of small differences in LCC shear strength or a benefit of the more distributed reinforcing provided by the welded-wire reinforcement. In either event, the performance of the reinforcement and MSE wall panels was very good until failure of the LCC. In addition to these two tests, the research team conducted an improvised lateral load test on a test pile located about 5 pile diameters behind the MSE wall with welded-wire reinforcement after completion of the surcharge test. We used two electric winches to pull the 12.75 inch diameter steel pipe pile into the LCC backfill between the welded-wire reinforcement. The test pile easily “cookie-cut” into the LCC to a depth of 10 feet with relatively low driving force, which was measured. Fig. 4 provides a plot of the lateral load vs. horizontal displacement curve for the test pile (at 12 inch above LCC surface) and at the top of the MSE wall. A maximum lateral load of about 30 kips was achieved at a pile head deflection of about 1 inch after which the LCC and MSE wall began deforming essentially together with further displacement but without a significant decrease in pile head resistance. The response was surprisingly ductile out to total pile head deflections of over 2 inches. A large crack developed parallel to the MSE wall face at 8 ft behind the wall, which is the location of the reinforcements. This crack grew in width with increased pile head deflection indicating that the reinforced LCC block was failing. When the load on the pile was removed, the LCC block rebounded and nearly closed the gap behind the reinforced zone.**Fig. 4. Plot of lateral pile head load vs. deflection for lateral pile load test on 12.75-inch diameter steel pipe pile located 5 pile diameters behind the back of the MSE wall.** |
| **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 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. |