**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, 2021)  \_ Quarter 2 (April 1 – June 30, 2021)  \_ Quarter 3 (July 1 – September 30, 2021)  **x 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](mailto:davidstevens@utah.gov) |
| **Lead Agency Project ID:**  FINET 42096, ePM PIN 17824  UDOT 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, 2022 (scope) | | **Number of Extensions:**  1 |

Project schedule status:

\_ On schedule \_ On revised schedule \_ Ahead of schedule **X** 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 = $337,500.00  Obligated to date = $337,500.00  (incl. $7,500 state match on FHWA contrib.)  Contract amount = $325,578.00  Remaining on contract = $197,401.51 | Contract spent = $128,176.49  Contract support = $369.01  Total spent = $128,545.50 | 50% |

***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 | 70% |

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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 survey  2. Basic material properties lab testing  3. Unreinforced LCC large-scale testing  4. 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 methods  6. Final Reports for (a) the unreinforced LCC test and (b) the reinforced LCC tests  7. Meetings and dissemination of results  The 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** – 95% complete. Worked on interim reports for Reinforced LCC Tests 3 and 5 including material testing. BYU submitted the interim report for Reinforced LCC Test 5 – MSE wall test with welded-wire reinforcement.  **Task 5** – 20% complete. Continued work on interim reports on key parameters from the unreinforced test and the reinforced tests.  **Task 6** – Worked on Final Report for the unreinforced LCC test.  **Task 7** – No TAC meetings were held this quarter.  **Contract** – No changes were made this quarter. |
| **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 Test 3 (lower strength LCC backfill) and Test 4 (reinf. pull-out tests). UDOT will share the interim report for Reinforced LCC Test 5 with the TAC as previously submitted.  **Task 5** – Continue work on this task, including interim reports on key parameters from tests.  **Task 6** – Continue work on Final Report for the unreinforced LCC test.  **Task 7** – Schedule and hold a TAC web conference to discuss the most recent testing and analysis results.  **Contract** – No changes are planned in the next quarter. Discuss with the TAC the possibility of supporting the evaluation of an upcoming reinforced LCC wall-bridge project in Washington State through this pooled fund study. |

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| **Significant Results:**  During the past two quarters the research team has been evaluating the strain from the load tests. We hope to have plots available for the next quarterly report. We have also been working on the write-ups for the various tests that have been performed.    In the third quarterly report, we produced plots of the friction ratio, F\*, vs. vertical stress for ribbed strip reinforcement based on pull-out tests conducted within the LCC test box at a variety of vertical pressure along with supplemental pull-out tests in smaller boxes to fill in gaps in the data at select vertical pressures. These tests were performed in class II LCC with unconfined compressive strengths of about 100 psi. As shown in Fig. 1, the F\* values were consistent with additional testing previously reported by Reinforced Earth Co. and researchers from the Univ. of Kansas. The F\* values decreased with depth but were consistently higher than those recommended by AASHTO for granular soil above vertical pressures of above 800 psf. However, at higher vertical pressures, the F\* values were about the same as those for granular soils. A tentative design curve, modified slightly from the third quarter report, is also provided in Fig. 1.    **Fig. 1. F\* vs. vertical stress data points from pull-out tests on ribbed-strip reinforcements in LCC conducted at BYU along with data points obtained from pull-out tests conducted by Reinforced Earth Co. and University of Kansas (both Unpublished). Design curves for ribbed-strip reinforcements in soil (AASHTO) and in LCC (RECo) are also shown along with a tentative design curve based on all available data.**  It should be recognized that F\* design curves have typically been based on a conservative lower-bound envelope of the measured F\* values rather than averages of the F\* values because of the significant variation in the measured values, particularly at shallow depths (lower vertical stresses). Based on this practice, we have proposed a tentative F\* versus vertical pressure design curve, that allows for higher F\* values in comparison with both the RECo and AASHTO design curves. This design curve could be useful in design until additional testing provides better guidance. It should be noted, however, that the difference between our tentative F\* design curve and the AASHTO curve for granular soil becomes relatively small as pressure increases.  Plots of the friction ratio, F\*(St/t), vs. vertical stress for welded-wire reinforcement, based on pull-out tests conducted within two of the LCC test boxes at a variety of vertical pressures, are plotted in Fig. 2. St is the spacing between crossbars while t is the diameter of the crossbar. Pull-out resistance was selected as the highest value at a displacement less than or equal to a reinforcement deflection of 0.75 inch, although the pull-out resistance typically continued to increase significantly beyond this displacement level. The welded-wire reinforcements consisted of a ladder of two W11 longitudinal bars with two, three, or four crossbars consisting of a W11 (0.375-inch) diameter bar (t) that was 10.5 inches long with a longitudinal spacing (St) of 12 inches between cross-bars. These tests were performed in class II LCC with unconfined compressive strengths of about 100 psi. F\* values from previous testing on welded-wire reinforcements in Class II LCC reported by SSL at a vertical stress of 30 psf are also shown in Fig. 2. The F\* values from the BYU and SSL tests show a consistent trend. The F\* values decreased with depth but were consistently higher than those recommended by AASHTO for granular soil for vertical pressures above 800 psf. However, at higher vertical pressures, the F\* values were about the same as those for granular soils. These results are consistent with the results from the ribbed-strip reinforcements. A tentative design curve is also provided in Fig. 2, and that becomes coincident with the curve for granular soil at vertical stresses greater than about 800 psf. A somewhat less conservative design curve might be appropriate as additional pull-out data is accumulated.    **Fig. 2. F\*(St/t) vs. vertical stress data points from pull-out tests on welded-wire reinforcements in LCC conducted at BYU along with data points obtained from pull-out tests conducted by SSL, LLC (Unpublished). Design curves for welded-wire reinforcements in granular soil (AASHTO) are also shown along with a tentative design curve for LCC based on all available data.** |
| **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. |