**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)  **x 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](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 | 40% |

***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** |
| 9% | $30,413.49 | 57% |

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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. Started the literature review and prepared a survey.  **Task 2** – 100% complete.  **Task 3** – 100% complete.  **Task 4** – 90% complete. Completed interim report for Reinforced LCC Test 5 and worked on interim reports for Reinforced LCC Tests 3 and 4 including material testing.  **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. Some of the study results were presented by Dr. Rollins at the 45th Annual Northwest Geotechnical Workshop hosted by UDOT in September.  **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 the Test 3 (lower strength LCC backfill), Test 4, and Test 5.  **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 quarter we computed the friction ratio, F\*, from pull-out load tests on 8-ft long ribbed-strip reinforcements that were conducted as part of Task 4. These tests were performed in class II LCC with unconfined compressive strengths of about 100 psi. Six of these tests were performed at very low vertical stress values (50 to 170 psf) representing LCC depths of 1.6 to 5.7 ft while an additional six tests were performed at higher pressures (1500 to 1600 psf) applied by a uniform surcharge over the surface of the LCC block. These higher pressures represent the equivalent of 50 ft of LCC with a unit weight of about 30 lbs/ft3. Multiple tests were performed in each pressure range to consider the potential variability in the compressive strength. To provide F\* values for intermediate pressures (600 and 1050 psf) additional pull-out tests were subsequently conducted on four separate LCC blocks using 6-ft long ribbed-strip reinforcements with vertical load applied by dead load consisting of concrete blocks.  Fig. 1 provides a plot of the F\* values as a function of vertical stress at the level of the reinforcement from the BYU tests with blue round markers. The F\* values decrease with vertical stress, and the variability in the F\* values also appears to decrease substantially with vertical stress. To provide additional context for the results of the BYU pull-out tests, F\* values obtained from a number of pull-out tests on ribbed-strip reinforcements reported by The Reinforced Earth Company (RECo) are also shown in green triangular markers in Fig. 1. In addition, results from pull-out tests conducted on ribbed-strip reinforcements by Univ. of Kansas (U of K) researchers, presented in recent webinars, are also shown with open square markers in Fig. 1. The agreement between the BYU tests and those from RECo and U of K is very good throughout the range of vertical pressures involved. Since each of the test series were conducted independently using different test arrangements and details, the agreement between the various tests adds confidence to the reliability of the overall results.  F\* versus vertical pressure design curve recommended by AASHTO for ribbed strip reinforcements is also plotted in Fig. 1 for comparison. This design curve has been computed assuming a unit weight of 120 lbs/ft3 for a sand backfill. The measured F\* values all plot considerably beyond the AASHTO design curve, particularly at low pressure, but are just to the right of the curve at greater pressures. The tentative design curve suggested by RECo based on their limited set of pullout test results is also shown in Fig. 1. Although the RECo curve is higher than the AASHTO curve near the ground surface, it is lower than the AASHTO curve at comparable pressures.  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. 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 becomes relatively small as pressure (depth) increases. Therefore, it might be desirable to adjust the tentative design curve in the future.      **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.** |
| **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. |