**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(264)** | | **Transportation Pooled Fund Program - Report Period:**  \_ Quarter 1 (January 1 – March 31, 2017)  **x Quarter 2 (April 1 – June 30, 2017)**  \_ Quarter 3 (July 1 – September 30, 2017)  \_ Quarter 4 (October 1 – December 31, 2017) | |
| **Project Title:**  Passive Force-Displacement Relationships for Skewed Abutments | | | |
| **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 42051, ePM PIN 10903  UDOT PIC No. UT11.406 | **Other Project ID (i.e., contract #):**  UDOT Contract No. 138123 | | **Project Start Date:**  August 13, 2012 |
| **Original Project End Date:**  September 30, 2014 | **Current Project End Date:**  December 30, 2018 | | **Number of Extensions:**  4 |

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** |
| $400,000.00 (current contract)  $400,000.00 (total committed) | $226,500.00 | 70% |

***Quarterly*** Project Statistics:

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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 | 77% |

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| **Project Description**:  At present, about 40% of the 600,000 bridges in the FHWA database are constructed at a skew angle (Silas Nichols, Personal Communication). There is considerable uncertainty about the passive force on skewed abutments where the passive force develops at an angle relative to the longitudinal axis of the bridge structure. Although current design codes (AASHTO 2011) consider that the ultimate passive force will be the same for a skewed abutment as for a non-skewed abutment, numerical analyses performed by Shamsabadi et al. (2006) indicate that the passive force will decrease substantially as the skew angle increases. Reduced passive force on skewed abutments would be particularly important for bridges subject to seismic forces or integral abutments subject to thermal expansion. Unfortunately, there have not been any physical test results for skewed abutments reported in the literature which could guide engineers in making appropriate adjustments for skewed conditions. Nevertheless, some field evidence has clearly shown poorer performance of skewed abutments during seismic events and distress to skewed abutments due to thermal expansion (Shamsabadi et al. 2006, Steinberg and Sargand 2010).  This study builds on previous pooled fund testing conducted by Rollins and his students at BYU to evaluate passive force-deflection relationships for non-skewed abutments (TPF-5(122), Dynamic Passive Pressure on Abutments and Pile Caps, Rollins et al, 2010). The test facilities can readily be modified to allow for the test program with relatively small additional costs because of the test fixtures (reaction shafts, reaction walls, and pile supported cap) which are already constructed at the site. Results from this study can be compared with previous testing to assess overall performance.  Four objectives are outlined for Phase I of this study:   1. Determine static passive force-displacement curves for skewed abutments with and without wingwalls from large scale tests. 2. Provide comparisons of behavior of skewed abutments with that of normal abutments. 3. Evaluate the effect of wingwalls on skewed abutment response. 4. Develop design procedures for calculating passive force-displacement curves for skewed abutments.   Phase II objectives focus on passive force-deflection relationships for Controlled Low-Strength Material (CLSM) (a.k.a. flowable fill, cellular concrete, etc.) backfill and the influence of skew angle and rotation.  Phase I tasks for this study include:  I-1. Literature Review and Collection of Existing Test Data  I-2. Perform Laboratory Passive Force-Deflection Tests on 2 ft High Wall with Skew Angles of 0º, 15º, 30º, and 45º  I-3. Perform Field Passive Force-Deflection Tests on 5.5 ft High Wall with Skew Angles of 0º, 15º, and 30º and Transverse Wingwalls  I-4. Perform Field Passive Force-Deflection Tests on 5.5 ft High Abutment with Skew angles of 0º, 15º, 30º and MSE Wingwalls  I-5. Calibrate Computer Model and Conduct Parametric Studies  I-6. Preparation of Final Report  I-7. Perform Additional Field Passive Force-Deflection Tests on 5.5 ft High Abutment with a Skew Angle of 45º with and without MSE Wingwalls  I-8. Perform Field Passive Force-Deflection Tests on 3.0 ft High Unconfined Backfill with Skew Angles of 0º and 30º  I-9. Perform Field Passive Force-Deflection Tests on 5.5 ft High Pile Cap with Concrete Wingwalls and Skew Angles of 0º and 45º  I-10. Perform Field Passive Force-Deflection Tests on 3.5 ft High Unconfined Gravel Backfill with Skew Angles of 0º and 30º  I-11. Perform Field Passive Force-Deflection Tests on 3.5 ft High GRS Gravel Backfill with Skew Angles of 0º and 30º  I-12. Present the Results of the Study at TRB and AASHTO Meetings  Phase II tasks for this study include:  II-1. Conduct literature review to define typical characteristics of CLSM backfill  II-2. Perform lab-scale passive force test with CLSM  II-3. Conduct large-scale passive force field tests with CLSM  II-4. Perform large-scale passive force tests with rotation and longitudinal displacement  II-5. Validate or calibrate computer models  II-6. Develop simplified design models to simulate observed performance  II-7. Prepare final report with design examples for typical cases  II-8. Disseminate results and work with sponsors and AASHTO to implement findings into future codes  Dr. Kyle Rollins of BYU is the Principal Investigator for this research project. Individual task reports will be prepared for Tasks I-1 through 5 and I-7 through 11, and for Tasks II-1 through 6, when these are completed. Phases I and II will have separate final reports. Two in-person meetings with the multi-state technical advisory committee (TAC) were held in Salt Lake City, Utah during the project. Other TAC meetings will be tele-conference or web meetings. |

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| **Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):**  Task I-1 – 100% complete.  Task I-2 – 100% complete.  Task I-3 – 100% complete.  Task I-4 – 100% complete.  Task I-5 – 80% complete. Continued work on RC Wingwall case.  Task I-6 – 50% complete. Progress was made on multiple draft final reports to be published. UDOT and the TAC continued reviewing draft final reports. Planned list of final reports is as follows:   * Passive force-deflection behavior of 5.5 ft skewed abutments with transverse wingwalls (45 degree skew tests added) * Passive force-deflection behavior of 5.5 ft skewed abutments with longitudinal MSE wingwalls (45 degree skew tests added) * Passive force-deflection behavior of 3 ft skewed abutments with transverse wingwalls (larger width-to-height ratio tests) *– draft received* * Passive force-deflection behavior of 5.5 ft abutments with longitudinal reinforced concrete wingwalls *– draft received* * Passive force-deflection behavior of 3.5 ft gravel and Geosynthetic Reinforced Soil (GRS) backfill with transverse wingwalls *– draft received* * Computer model calibration and parametric studies, Part 1 – Passive force-deflection modeling with no wingwall *– draft received* * Computer model calibration and parametric studies, Part 2 – Additional modeling with longitudinal reinforced concrete wingwalls, 45 degree skew, two-lane highway * Summary report on passive force-deflection behavior of skewed abutments (short report up to 20 pages)   Task I-7 – 80% complete. Continued data analysis and worked on task report.  Task I-8 – 90% complete. Draft final report for this task is complete.  Task I-9 – 90% complete. Draft final report for this task is complete.  Task I-10 – 90% complete.  Task I-11 – 90% complete. Combined draft final report for Tasks 10 and 11 is complete.  Task I-12 – 80% complete.  Task II-1 – 100% complete.  Task II-2 – 90% complete. Draft task report was shared with the TAC for review.  Task II-3 – 90% complete. Draft task report was shared with TAC for review.  Task II-4 – 80% complete. Field tests have been completed. Progress was made on task report.  Task II-5 – Computer models are being incorporated in the other Phase II reports.  Task II-6 – Simplified design models are being incorporated in the other Phase II reports.  Task II-7 – None.  Task II-8 – None.  TAC Meetings – None this quarter.  Contract – No changes this quarter. |
| **Anticipated work next quarter:**  Task I-1 – None.  Task I-2 – None.  Task I-3 – None.  Task I-4 – None.  Task I-5 – Continue work on RC Wingwall case.  Task I-6 – Continue work on multiple draft final reports to be published, including UDOT and TAC reviews. Combine portions of other task reports for the Final Summary Report.  Task I-7 – Complete the draft final report for this task.  Task I-8 – Revise the draft final report for this task based on TAC feedback.  Task I-9 – Revise the draft final report for this task based on TAC feedback.  Task I-10 – Revise the draft final report for this task based on TAC feedback.  Task I-11 – Revise the draft final report for this task based on TAC feedback.  Task I-12 – Refine proposed code changes with the TAC in preparation for 2017-2018 interaction with AASHTO SCOBS. Prepare to publish a peer-reviewed paper on the study as a reference that could be noted in the code.    Task II-1 – None.  Task II-2 – Receive TAC review comments on the task report and update the report.  Task II-3 – Receive TAC review comments on the task report and update the report.  Task II-4 – Complete work on the task report and share with TAC for review.  Task II-5 – Continue incorporating computer models in the other Phase II reports.  Task II-6 – Continue incorporating simplified design models in the other Phase II reports.  Task II-7 – None.  Task II-8 – None.  TAC Meetings – Plan to hold a web conference TAC meeting in September 2017 to discuss new results, report reviews, and implementation.  Contract – No revision planned. |

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| **Significant Results:**  During this quarter, data reduction efforts have been focused on the tests involving inclined loading with sand backfill for the 0º and 30º skew abutments. Figure 1 shows plots of the longitudinal displacement of the backfill soil for the 0º and 30º skew abutments along with the failure surfaces. For the 0º skew, the failure surface developed about 17 ft. behind the abutment wall and was parallel to the wall. Displacements were somewhat higher on the right side of the wall. For the 30 skew, the failure plane developed about 18 ft behind the acute point of the wall but was further from the abutment face on the right side. This could be a result of the inclined loading which pushed the right side of the abutment wall at a greater displacement than the left side. A review of the longitudinal displacement contours for the 30º skew case indicates that a wedge of soil between the abutment and the longitudinal wing wall on the right side has been locked in place and is essentially moving with the abutment wall. As a result, the “effective skew angle” of the abutment becomes smaller than the actual skew angle of the abutment wall. This is likely the reason that the reduction in passive force observed for this test was not as great as would be predicted by the design equation. Similar behavior was observed for the tests conducted with the trapezoidal reinforced concrete wingwalls. As the width of the abutment becomes larger, this effect is likely to be reduced, as indicated by numerical modeling, and will be similar to that predicted by the reduction factor.    **Figure 1. Contours of longitudinal backfill displacement for sand backfill tests with inclined loading for zero skew test (left side) and 30º skew test (right side).**  Pressure plates were installed on the back of the abutment wall for the 30 skew test to investigate whether the pressure distribution would be different with an inclined loading in which displacement was greater on the right side than the left side. Figure 2 provides a plot of the measured pressure at six sensors along the back of the wall for five average backwall longitudinal displacement values. For the smallest backwall displacement the pressure is relatively uniform.  However, at larger displacements there is a trend for the pressure to be larger on the right side of the pile cap where displacements are greater, as might be expected. Two of the sensors appear to be under-registering the pressure in comparison to the surrounding pressure sensors. Figure 3 provides a comparison of the passive force obtained from the actuator loading in comparison with the passive force obtained from the pressure cell readings. The passive force from the pressure cells was computed by multiplying the pressure reading by the tributary area for the cell. The passive force obtained from the pressure cells is typically lower than measured by the actuators, but the trends are consistent and the difference at the peak load is only about 10%. If the low readings from the two pressure sensors are replaced by values interpolated from the remaining sensors, better agreement might be achieved.      **Figure 2. Measured earth pressure on the back of the “abutment wall” for the 30º skew test. Pressures distributions are shown for five average backwall longitudinal displacement levels.**  **Figure 3. Comparison of passive force-deflection curves obtained from hydraulic actuators and pressure cells on the back of the pile cap.** |
| **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).** |
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| **Potential Implementation:**  UDOT is considering early adoption of the skew reduction factor for passive force based on the laboratory and field test results. In June of 2013, 2014, and 2016, Dr. Rollins presented the results of the research to date to technical committees at the AASHTO Subcommittee on Bridges and Structures Annual Meetings in Oregon, Ohio, and Minnesota on behalf of the project TAC. This interaction is intended by the TAC and Dr. Rollins to prepare the way for design code revisions once the research is completed. Caltrans is also promoting use of the research results in their design methods. Dr. Rollins is proposing changes to the AASHTO code, and we will continue to promote these to the TAC and AASHTO SCOBS. |