**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, 2014) \_ Quarter 2 (April 1 – June 30, 2014)\_ Quarter 3 (July 1 – September 30, 2014)**x Quarter 4 (October 1 – December 31, 2014)** |
| **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 |
| **Lead Agency Project ID:**FINET 42051, ePM PIN 10903UDOT 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 15, 2015 | **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** |
| $270,000.00 | $139,200.00 | 60% |

***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 | 70% |

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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 this new 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.

The scope of work consists of twelve specific tasks, including new tasks 7 through 12: 1. Literature Review and Collection of Existing Test Data
2. Perform Laboratory Passive Force-Deflection Tests on 2 ft High Wall with Skew Angles of 0º, 15º, 30º, and 45º
3. Perform Field Passive Force-Deflection Tests on 5.5 ft High Wall with Skew Angles of 0º, 15º, and 30º and Transverse Wingwalls
4. Perform Field Passive Force-Deflection Tests on 5.5 ft High Abutment with Skew angles of 0º, 15º, 30º and MSE Wingwalls
5. Calibrate Computer Model and Conduct Parametric Studies
6. Preparation of Final Report
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
8. Perform Field Passive Force-Deflection Tests on 3.0 ft High Unconfined Backfill with Skew Angles of 0º and 30º
9. Perform Field Passive Force-Deflection Tests on 5.5 ft High Pile Cap with Concrete Wingwalls and Skew Angles of 0º and 45º
10. Perform Field Passive Force-Deflection Tests on 3.5 ft High Unconfined Gravel Backfill with Skew Angles of 0º and 30º
11. Perform Field Passive Force-Deflection Tests on 3.5 ft High GRS Gravel Backfill with Skew Angles of 0º and 30º
12. Present the Results of the Study at TRB and AASHTO Meetings

Dr. Kyle Rollins of BYU is the Principal Investigator for this research project. Individual task reports will be prepared for Tasks 1 through 5 and 7 through 11 when these are completed. Up to two in-person meetings with the multi-state technical advisory committee (TAC) are planned to be 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 1 – 100% complete. Task 2 – 100% complete. Task 3 – 100% complete. Task 4 – 100% complete. Task 5 – 80% complete. BYU continued data analysis and worked on task report.Task 6 – 20% complete. Combining portions of other task reports for the Final Report.Task 7 – 80% complete. BYU continued data analysis and worked on task report.Task 8 – 80% complete. BYU continued data analysis and worked on task report.Task 9 – 80% complete. BYU continued data analysis and worked on task report.Task 10 – 80% complete. BYU continued data analysis and worked on task reports. Task 11 – 80% complete. BYU continued data analysis and worked on task reports. They submitted a preliminary task report, which was shared with the TAC.Task 12 – 60% complete.TAC Meetings – None held this quarter.Contract – No adjustments this quarter. |
| **Anticipated work next quarter**:Task 1 – None.Task 2 – None.Task 3 – None.Task 4 – None.Task 5 – Work will continue on the task report.Task 6 – Combining portions of other task reports for the Final Report.Task 7 – Complete the full task report (the revised Tasks 3 and 4 reports).Task 8 – Complete the full task report.Task 9 – Complete the full task report.Task 10 – Complete the full task report.Task 11 – Complete the full task report.Task 12 – Prepare for upcoming AASHTO SCOBS meetings, with TAC input, to encourage implementation of research results.TAC Meetings – We will hold a TAC web conference to discuss completed task reports during this quarter. Discussion may also include a related new field testing task to potentially add to the research contract.Contract – None. |

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| **Significant Results:**Efforts during the past quarter have generally focused on integrating the previous individual task reports into one consistent and coherent document. In addition, analyses have been performed with the computer models PYCAP and ABUT to evaluate the ability to predict the measured passive force-deflection relationships with these models. In addition, comparisons have been made with procedures outlines in AASHTO. With respect to the tests involving GRS backfills, it was necessary to perform interface tests to evaluate this effect on lateral resistance and its development with displacement. The results from these tests are outlined subsequently.A modified direct shear test was performed to determine the interface friction between the geofabric and the concrete pile cap. A standard direct shear machine was used with the 2 in. thick by 4 in. diameter circular shear box. The concrete pile cap was cored to obtain a 1 in. thick by 4 in. diameter sample core. The outer concrete surface faced up in the lower mold to form the lower interface of the test. A 4 in. diameter sample of the geofabric was then cut to fit and placed on top of the concrete as the face of the upper mold. Gravel backfill obtained from the test site filled the space behind the fabric. The soil was screened by the No. 4 sieve, wetted to the average testing moisture content of 6.2%, and placed behind the fabric at the greatest hand compaction possible. The compaction achieved was approximately 94% for the two lower-pressure tests and 88% for the two higher pressure tests. One 0.25 in. thick porous stone was placed on top. The test was then performed four times with varying vertical pressures that correlated with the estimated lateral earth pressures against the concrete-fabric interface during testing. The passive earth pressure coefficient assumed was Kp=10, and the backfill passive pressure was calculated using the equation pp = KpγH. Table 1 shows how the four vertical loads correspond to loads at varying backfill depths during abutment testing. Figure 1 presents the shear stress vs. displacement curves obtained from the testing. The test with Pv = 504 lb (5923 psf) is dashed because the passive earth pressure it represents would occur at 4.1 ft, which is deeper than the backfill used during abutment testing. Similar to stress-strain plots for strain hardening materials, the system had a yield point where tangent stiffness greatly decreased, but did not drop to zero.. The stress continued to increase past this yield point, though at a slower rate. The capacity of the shear machine prevented further horizontal displacement to try to obtain an absolute maximum peak from these tests. Table 1. Correspondence of Vertical Load Used in Direct Shear Tests to Horizontal Forces in GRS Backfill During Abutment Testing

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| Backfill Depth | Passive Earth Pressure Coeffient Assumed, Kp | Moist Unit Weight | Passive (Horizontal) Stress in Backfill | Vertical Stress in Direct Shear Test | Vertical Load in Direct Shear Test |
| [ft] |   | [pcf] | [psf] | [psf] | [lb] |
| 1.0 | 10 | 144.1 | 1398 | 1398 | 119 |
| 1.7 | 10 | 144.1 | 2432 | 2432 | 207 |
| 3.1 | 10 | 144.1 | 4442 | 4442 | 378 |
| 4.1 | 10 | 144.1 | 5923 | 5923 | 504 |

When the peak value was taken at the yield point, the resulting concrete-fabric interface friction angle was 20.6°, about 45% of the friction angle of the gravel used for the backfill, 45.8°, with no apparent cohesion. Because the load steadily increased, another friction angle was calculated from the stresses using the last 10 data points of each test, at the approximate horizontal displacement of 0.25 in. The end-of-test concrete-fabric interface friction angle was 26.1°, 57% of the soil friction angle, with an apparent cohesion of 680 psf. Figure 2 and Figure 3 show the shear vs normal stress plots at these two points of testing. The measured stress-displacement curves and friction angles seem to be reasonable based on load test where it appeared that the passive force had peaked, but then the passive resistance gradually continued to increase with displacement. This behavior appears to be related to the interface behavior between the concrete and geosynthetic sheet. As reported in the FHWA manual on Mechanically Stabilized Earth walls, the frictional resistance of geosynthetics sheets requires considerably more wall movement to mobilize the full lateral resistance than metallic strips for instance. Therefore, the field tests and laboratory tests seem to be consistent with experience with these geosynthetics in other applications. Figure 1: Shear stress vs. displacement curves for the four modified direct shear tests performed for the fabric-to-concrete interface.Figure 2: Shear vs. normal stress plots for modified direct shear tests using the stresses at the point of yielding.Figure 3: Shear vs. normal stress plots for modified direct shear tests using the stresses at the end of testing.  |
| **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).**Some of the analysis in the newer tasks has taken longer than originally planned. When the newer field testing tasks were added to the contract, the contract end date was not extended. The contract was subsequently amended to reflect a revised schedule to complete all tasks and deliverables by the end of 2015. |

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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, but no final decision has been made at this point. In June 2013 and June 2014, 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 and Ohio 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. |