**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:** **x Quarter 1 (January 1 – March 31, 2013)** \_ Quarter 2 (April 1 – June 30, 2013)\_ Quarter 3 (July 1 – September 30, 2013)\_ Quarter 4 (October 1 – December 31, 2013) |
| **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:**5H06852H, 42051, ePM PIN 10903UDOT PIC No. UT11.406 | **Other Project ID (i.e., contract #):** UDOT Contract No. 13-8123  | **Project Start Date:** August 13, 2012 |
| **Original Project End Date:**September 30, 2014 | **Current Project End Date:** September 30, 2014 | **Number of Extensions:** |

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** |
| $150,000.00 | $70,000.00 | 50% |

***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** |
| $35,000.00, 23% | $35,000.00 | 28% |

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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 six specific tasks: 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

Dr. Kyle Rollins of BYU is the Principal Investigator for this research project. Individual task reports will be prepared for Tasks 1 through 5 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.):**Dr. Rollins of BYU and his student presented results of the research in a technical session at the 2013 TRB Annual Meeting in January.A TAC meeting was held in Salt Lake City on February 7, 2013, and was attended by most TAC members in person and by others via web conference. Dr. Rollins used computer presentations and group discussion to share results to date from Tasks 1 through 4 and to outline additions to the project scope based on requests from TAC members and available funding. Preferred additions to the project included field tests using 45º abutment skew, Geosynthetic Reinforced Soil (GRS) abutment, concrete wingwalls, and/or different soil types. Plans were discussed for Dr. Rollins and TAC members to approach the appropriate AASHTO committees regarding getting on their 2013 agendas to present the research results. At the February TAC meeting additional presentations were given by UDOT on their upcoming GRS abutment/bridge replacement project on I-84, and by BYU on D4AR technology that can be used with video imagery and modeling for displacement monitoring using point cloud methods.BYU prepared a preliminary field test report for Task 4 and a detailed draft report for Task 3, and these were shared with the TAC for review. BYU continued data reduction and analysis for these two tasks.BYU prepared a revised project work plan, and this was circulated to the TAC for review. The total cost of contract and proposed additional work on this project is $255,000, equal to the total funding commitments from the pooled fund partners. |
| **Anticipated work next quarter**:The contract will be modified based on the approved revised work plan. BYU will prepare a detailed draft report for Task 4 and share this with the TAC for review. BYU will continue data reduction and analysis for Tasks 3 through 5.BYU will conduct the new field testing in May and June 2013.Dr. Rollins will attend AASHTO meetings in May 2013 to present results of the research on behalf of the project TAC. |

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| **Significant Results:**Additional results from Tasks 3, 4, and 5:Analysis of the measured passive force-deflection curves was performed using a hyperbolic load-deflection curve with the ultimate resistance obtained from the log spiral method. As shown in Fig. 1, very good agreement with the measured curve for the unconfined backfill at zero skew was obtained using a 39.5º friction angle for the backfill (from direct shear test). The Brinch-Hansen equation was used to account for 3D edge effects.Fig. 1. Comparison of measured and computed passive force-deflection curves for zero skew test with unconfined backfill with friction angle of 39.5 degrees for the backfill. When the same friction angle (39.5º) was used to analyze the load-deflection curve for the backfill confined by MSE wingwalls, the predicted ultimate resistance was significantly lower than the measured curve as shown in Fig. 2. To obtain agreement with the measured curve, it was necessary to use a friction angle of 47.1º. The increased resistance can be explained by two factors. First, with the MSE wingwalls, the backfill is under plane strain conditions and the plane strain friction angle would be expected to be about 12% higher than the triaxial friction angle. Second, the reinforcements within the soil might be expected to increase the frictional resistance as shear plane extended back into the fill material. Fig. 2. Comparison of measured and computed passive force-deflection curves for zero skew test with MSE wingwalls confining the backfill with friction angles of 39.5º (triaxial) and 47.1º (plane strain) for the backfill. Analysis of the internal shear planes for the test with unconfined backfill provides a potential explanation of the decrease in passive force as skew angle increases. For both the 0° and 15° tests the internal shear planes were remarkably similar to the log-spiral shear planes described by Terzaghi (1943). Specifically, there was a curved lower shear plane that progresses first downward from the bottom of the backwall and then up to the surface of the backfill at an angle with the horizontal approximately equal to 45° - φ/2, and an upper shear plane that descended from the top of the backwall to intersect the rising shear plane at an angle with the horizontal also approximately equal to 45° –φ/2 as shown in Fig. 3. Neither the Rankine nor Coulomb failure geometries predict this upper failure surface. However, for the 30º skew angle the internal shear surfaces shown in Fig. 4 are much more linear and the upper shear surface is no longer developed. These failure surfaces are much closer to the failure surface predicted by the Rankine method where friction on the wall surface is zero. Because the Rankine failure wedge involves a much smaller volume than the log-spiral volume, the passive force is significantly smaller. This difference in the failure mechanism may potentially explain the lower passive force as skew angle increases. The reduction in effective wall friction angle could be due to the increased shear stress on the wall surface for the 30º skew test. For this skew angle the shear stress applied along the soil-wall interface is approximately equal to the shear resistance. This could lead to a case where there is insufficient friction on the interface to develop the full passive resistance.Fig. 3. Measured internal shear planes for the passive force test on unconfined backfill with a zero degree skew angle showing curved failure surfaces typical of log-spiral failure geometry. Note the presence of upper shear surface extending downward from the top of the wall to the failure surface.Fig. 4. Measured internal shear planes for the passive force test on unconfined backfill with a 30 degree skew angle showing more linear failure surfaces typical of Rankine failure geometry. Note that no upper shear plane is evident. |
| **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).**After the original contract was authorized, additional funding was committed to the project by other states and FHWA. With these new funds, the scope of work will be expanded to include more features in the field testing. This could cause the schedule to shift to compensate for the extra work. The recommended solution is to get input from the TAC and then modify the contract scope, amount, and schedule as needed, while limiting the shift in project end date. |

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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. With BYU’s help, UDOT plans to get the topic and research results on the agenda of the relevant AASHTO committee(s)/subcommittee(s) meetings in 2013. |