**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.*

|  |  |
| --- | --- |
| **Transportation Pooled Fund Program Project #****TPF-5(264)** | **Transportation Pooled Fund Program - Report Period:**\_ Quarter 1 (January 1 – March 31, 2015) **x Quarter 2 (April 1 – June 30, 2015)**\_ Quarter 3 (July 1 – September 30, 2015)\_ Quarter 4 (October 1 – December 31, 2015) |
| **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:

|  |  |  |
| --- | --- | --- |
|  **Total Project Budget** |  **Total Cost to Date for Project** |  **Percentage of Work**  **Completed to Date** |
| $270,000.00 | $160,800.00 | 65% |

***Quarterly*** Project Statistics:

|  |  |  |
| --- | --- | --- |
|  **Total Project Expenses**  **and Percentage This Quarter** |  **Total Amount of Funds**  **Expended This Quarter** |  **Total Percentage of**  **Time Used to Date** |
| 8% | $21,600 | 85% |

|  |
| --- |
| **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. |

|  |
| --- |
| **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 – 30% complete. BYU combined portions of other task reports for the Final Summary Report. A plan for multiple final reports to be published, based on results of related tasks and including a brief summary report with the main design recommendations, was introduced to the TAC.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. Draft final report on this task was shared with the TAC for review.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.Task 12 – 60% complete.TAC Meetings – A web conference TAC meeting was held on May 27. Dr. Rollins provided an update on project tasks and findings. The group also discussed next steps and the possibility of adding a new, related field testing task to the project, with primary interest from the TAC members from Caltrans.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 – Combine portions of other task reports for the Final Summary Report.Task 7 – Complete the full task report (the revised Tasks 3 and 4 reports).Task 8 – Complete the full task report.Task 9 – Revise the draft final report for this task based on TAC feedback.Task 10 – Complete the full task report.Task 11 – Complete the full task report.Task 12 – None.TAC Meetings – We will hold a TAC web conference to discuss additional results and completed reports.Contract – Dr. Rollins and UDOT will work with interested TAC members on developing a work plan and identifying funding sources for a new field testing task, involving passive force/skewed abutments using controlled low-strength material (CLSM) as backfill, and potentially some baseline push-and-rotate tests on the test abutment/pile cap. |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Significant Results:**Work this quarter has focused on completion of the final report for tasks 10 and 11 which are being combined into one document because both involve gravel backfill. This approach facilitates comparisons between both tests and comparison of analysis parameters. A draft report is now completed and is currently under final review for submittal to the TAC members. Lateral passive force analyses were completed using the computer models PYCAP, developed by Mokwa and Duncan (2001) as well as ABUTMENT, developed by Shamsabadi et al (2007). Results from the PYCAP analyses have been presented previously. Like PYCAP, ABUTMENT also models the passive force-deflection curve hyperbolically but is based more on forces than on moments. The method specified in the program was Log Spiral Forces Method Composite, and 3D geometry was selected. Failure planes were specified from the top down, and stress/strain was calculated with the modified hyperbolic method. The results from ABUTMENT provided very good agreement with the gravel test data and with PYCAP results with very little adjustment of soil parameters and ABUTMENT default values. The computed curves are compared with the measured curves in Figure 1, and the inputs are listed in Table 1. The adjustment to the soil friction angle from 45.8° to 45.6° was very small and well within the variability allowed by using only two direct shear field test points. The wall interface friction angle ratio (δ/φ) was kept at 66%. Remaining soil parameters are equivalent to those input into PYCAP. The parameter ε50 represents the strain at which 50% of the ultimate passive force is reached. Shamsabadi et al. (2007) recommends a range of 0.001 to 0.005 for gravels. The ε50 value that best fit the data was 0.0075, which indicates that the large displacements required to push this test without peaking were unusual, as previously discussed. The recommended range for the failure ratio is 0.94 to 0.98; 0.955 fits comfortably within that range. Adjusting the Δmax/H value in ABUTMENT with the ε50 value was more difficult than in PYCAP, thus the skew reduction was excluded from this case.Figure 1. ABUTMENT best fit curve with 0° skew 3.5 ft gravel test data.Table 1: ABUTMENT Input Values for Gravel and GRS Tests

|  |  |  |  |
| --- | --- | --- | --- |
| *Soil Strength Parameter* | *Units* | *0° Gravel* *Inputs* | *0° GRS* *Inputs* |
| Cap Width, b | ft (m) | 11.0 (3.35) | 11.0 (3.35) |
| Cap Height, H | ft (m) | 3.5 (1.07) | 3.5 (1.07) |
| Soil Friction Angle, ϕ | deg | 45.6 | 45.8 |
| Wall Friction Angle, δ | deg | 30.1 | 25.8 |
| Cohesion, c | ksf (MPa) | 0 | 0 |
| Abutment Adhesion, Ca | ksf (MPa) | 0 | 0 |
| Soil Density, ɣ | kcf (kN/m^3) | 0.1449 (0.01825) | 0.1449 (0.01825) |
| ε50 | – | 0.0075 | 0.010 |
| Poisson’s Ratio, ν | – | 0.22 | 0.22 |
| Failure Ratio, Rf | – | 0.955 | 0.965 |
| Surcharge, q | ksf (MPa) | 0 | 0 |

The ABUTMENT analysis inputs for the GRS tests are also found in Table 1. The ABUTMENT analysis for GRS used the same soil and wall friction angles used in the PYCAP analysis of 45.8° and 25.8°, respectively. It also used a higher ε50 horizontal strain value (0.010) and higher failure ratio (Rf=0.965) than the gravel analysis in an effort to fit the shallower slope of the curve. Still, the shallow slope of the curve was difficult to match in ABUTMENT, as seen in Figure 2. This analysis confirms the likelihood that the reduced passive resistance in the GRS tests was due to both lower wall friction and greater displacement required to develop full passive resistance. The Rskew value of 0.63 was used with the ABUTMENT data to reduce it for a 30° skew analysis, which also had nearly as good agreement as PYCAP.Figure 2. ABUTMENT analysis for GRS tests using PYCAP inputs and ε50=0.010. |
| **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. Once the work plan for additional field testing with CLSM backfill and push-and-rotate tests is prepared, this will be incorporated into a new contract amendment which will also extend the contract end date through at least 2016. |

|  |
| --- |
| **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 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. |