**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(244)** | | **Transportation Pooled Fund Program - Report Period:**  \_ Quarter 1 (January 1 – March 31, 2015)  \_ Quarter 2 (April 1 – June 30, 2015)  \_ Quarter 3 (July 1 – September 30, 2015)  **x Quarter 4 (October 1 – December 31, 2015)** | |
| **Project Title:**  Shaking Table Testing to Evaluate Effectiveness of Vertical Drains for Liquefaction Mitigation | | | |
| **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 42046, ePM PIN 9933  UDOT PIC No. UT07.708 | **Other Project ID (i.e., contract #):**  UDOT Contract No. 138731 | | **Project Start Date:**  May 1, 2013 |
| **Original Project End Date:**  March 31, 2016 | **Current Project End Date:**  March 31, 2016 | | **Number of Extensions:** |

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** |
| $115,000.00 | $40,000.00 | 45% |

***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 | 90% |

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| **Project Description**:  The vision for this study is to determine the viability of large diameter (100 mm) prefabricated vertical drains for preventing liquefaction and associated settlements or lateral spreading under full-scale conditions. If viable, drainage alternatives offer substantial advantages in comparison to conventional densification approaches. In production, drains can often be installed at 25% to 40% of the cost of stone columns. In addition, the drains can be installed in about one-third to one-half of the time required for stone columns. Finally, the time and cost associated with post-treatment in-situ testing to evaluate improvement produced by densification may not be required with drains. In an era when construction budgets are becoming increasingly tight and projects are increasingly placed on fast-track schedules, innovative alternative solutions are required to deal with liquefaction hazards.  Although limited blast liquefaction testing (Rollins et al. 2003, Rollins et al. 2004), vibration testing (Chang et al. 2004) and centrifuge testing (Yang et al. 2004 ) suggest that vertical drains can be effective, no full-scale drain installation has been subjected to earthquake induced ground motions. This lack of performance data under full-scale conditions has been a major impediment to expanding the use of this technique. To remedy this problem we will conduct full-scale tests with vertical drains in liquefiable sand using the laminar shear box and high speed actuator system at NEES-Univ. at Buffalo. Tests will involve level ground conditions with two drain spacings and will be integrated with a previously funded NEESR study currently underway so that the control tests without drains will already be available. We will use the same sand installation techniques, as well as the same instrumentation plan and shaking protocols which have already been developed and proven successful. This collaborative approach will significantly reduce the cost of the study in comparison to a completely independent study. In addition, it will provide a comparison between the performance of the soil profile with drains relative to subsequent tests where piles will be involved. If full-scale tests prove the effectiveness of the drainage technique, significant time and costs savings can be achieved for both new construction and for retrofit situations.  Three objectives are outlined for this study:  1. Evaluate the ability of earthquake drains to reduce excess pore pressure and settlement for level ground conditions at progressively higher acceleration levels.  2. Define the influence of drain spacing on the effectiveness of the drains for mitigating liquefaction hazard.  3. Provide well-documented case histories which can be used to calibrate/validate numerical models for predicting the performance of vertical drains.  The scope of work consists of eight specific tasks:  1. Perform a literature review to summarize the state of the art in the area of liquefaction mitigation through drainage.  2. Conduct level ground shaking table tests with drains at 4 ft spacing.  3. Conduct level ground shaking table tests with drains at 3 ft spacing.  4. Reduce the test data, analyze, and compare with previous test on untreated sand.  5. Evaluate predictive methods by comparing measured behavior with behavior computed using computer models and simplified models.  6. Prepare a final report on effectiveness of the drain technique.  7. Disseminate the research results.  8. Hold technical advisory committee meetings.  Dr. Kyle Rollins of BYU is the Principal Investigator for this research project. The TPF-5(244) testing was performed at the SUNY-Buffalo shaking table testing facility in the summer of 2014. BYU was approved for shared-use status on the NEES-Buffalo shake table. 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.):**  Task 1 – 100% complete.  Task 2 – 100% complete.  Task 3 – 100% complete.  Task 4 – 100% complete. Report completed  Task 5 – 30% complete. BYU continued evaluating predictive methods.  Task 6 – No work yet.  Task 7 – No work yet.  Task 8 – 30% complete.  Contract – No adjustments. |
| **Anticipated work next quarter**:  Task 1 – None.  Task 2 – None.  Task 3 – None.  Task 4 – Report submitted  Task 5 – Continue with evaluating predictive methods.  Task 6 – None.  Task 7 – None.  Task 8 – Plan to hold another TAC web-conference to review and discuss additional results from the study.  Contract – The contract end date will be extended to provide additional time for completion of tasks and deliverables, at no additional cost to the project. |

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| **Significant Results:**  Most of the effort expended on the project in the past quarter has focused on completing a final report on the results of the two laminar shear box tests. The report also provides comparison with tests without drains where appropriate. The completion of the report is now imminent.  Fig. 1 provides a comparison of the excess pore pressure ratio time histories for laminar shear box tests with and without drains. Although the test without drains (LG0) had somewhat higher acceleration levels and shaking times than the test with drains (PVD-1), the differences in dissipation rates are important to consider. Liquefaction was developed in both tests. Similar data is presently unavailable for other tests without drains where acceleration and shaking times are more similar. Excess pore pressure ratios with drains are taken from round 1 of PVD-1 with a maximum acceleration of 0.2g and a duration of 7 seconds. In the tests without drains the maximum acceleration increased from 0.05g to 0.15g to 0.3g over a period of 35 seconds. The time history for the tests with drains has been shifted so that the shaking ends at the same time in each test.  For the test without drains, the sand remained liquefied (Ru=100%) after shaking ended for up to one minute at 4.33 feet or about 20 seconds at 12.41 feet. Water pressure dissipated from the bottom upward decreasing the rate of dissipation near the surface. Excess pore pressures are not reduced to Ru=50% in LG0 until approximately 125 to 160 seconds, depending on depth. In comparison, the excess pore pressure ratios from PVD-1 immediately begin to dissipate and are less than Ru=20% in about 15 seconds after shaking. At greater depths, the excess pore pressure ratio does not even reach Ru=100%. These results clearly show the beneficial effect of drains in rapidly reducing the excess pore pressures in a loose sand layer. This effect could be particularly helpful in reducing the development of water interlayer underneath low permeability layers which influence lateral spread displacement.    **Fig. 1 Comparison of excess pore pressure ratio (Ru) time histories for tests with and without drains.** |
| **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:** |