Project Summary – March 2019
TPF-5(296) Simplified SPT Performance-Based Assessment of Liquefaction and Effects

Start Date: March 2014
End Date: September 2018
Project Numbers: TPF-5(296), 14-8753, UT13.407
Cost: $179,500
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Summary of the Research:

This research was completed under pooled fund study TPF-5(296), led by the Utah Department of Transportation (UDOT) and supported by the Alaska, Connecticut, Idaho, Montana, Oregon, and South Carolina DOTs. This study was aimed at developing a better way to evaluate earthquake-induced soil liquefaction hazard and its effects. It demonstrated how current design approaches to predicting liquefaction and its effects are neglecting numerous uncertainties associated with the problem, resulting in inconsistent liquefaction hazard estimates across different seismic environments. Over the past twenty years, numerous researchers have demonstrated that the incorporation of uncertainties in the probabilistic computation of seismic hazards can lead to more consistent and objective estimates of hazard for use in design of structures and other infrastructure. This type of robust probabilistic analysis is commonly referred to as "Performance-based Design." However, the quantification and incorporation of these uncertainties, which in the case of liquefaction include ground motions, site amplification, triggering, and effects, are typically too difficult and/or impractical for geotechnical engineers to routinely perform on transportation projects.

In this study the researchers developed a simplified performance-based methodology to assess liquefaction triggering and several of its effects using data from the standard penetration test (SPT), a commonly-applied geotechnical engineering investigation technique for soils. The research produced a new Excel spreadsheet tool called SPLiq (Simplified Performance-based Liquefaction Analysis Tool) to implement the new simplified performance-based methodology. Liquefaction reference parameter maps, generated by the researchers based on current seismic source models from the U.S. Geological Survey (USGS), were incorporated in a publicly accessible online database for use with the SPLiq tool and the site-specific soil boring data. Using the simplified methodology and analysis tool, users can relatively quickly and with more certainty assess liquefaction triggering, post-liquefaction settlement, lateral spread displacement, and seismic slope displacement for highway projects.

This study was a pilot for the benefit of the states that participated in the pooled fund study. It demonstrated that a simplified performance-based liquefaction hazard estimate, that closely approximates (i.e., within 5%) the hazard value that would be obtained if the engineer

had performed the full performance-based analysis for the specific site, is achievable for more engineers, as long as the liquefaction parameter maps have been created for their state. Usefulness of the simplified approach could extend to other states, infrastructure, and industries in addition to highway transportation in the pooled fund states.

Implementation of the research results began with dissemination of the SPLiq tool and research reports to technical contacts in the pooled fund states and holding training workshops in each of the pooled fund states. The one-day workshops were given in 2016-2018 by the principal investigator of the research to consultants and state DOT engineers. Updated versions of the SPLiq tool and the liquefaction parameter maps were shared with the partner states through 2018. In its Geotechnical Manual of Instruction, the UDOT Geotechnical Division added the Simplified SPT Performance-based Assessment of Liquefaction and Effects procedure as UDOT's preferred analysis method for liquefaction triggering, lateral spread, and seismic settlement. UDOT engineers have observed that the SPLiq tool has been used by consultants for performing liquefaction hazard calculations for geotechnical reports on several projects already. This has been a great tool to check other methods that UDOT and consultants are currently using to make these predictions. It has also been observed that the simplified methodology tends to reduce the amount of predicted liquefaction hazard in Utah at the return periods prescribed for bridge and retaining wall design. This trend is consistent with those observed in other moderate- to low-seismicity states. As such, the implementation of SPLiq should result in an immediate economic benefit to UDOT and the state due to lower costs in design, construction, and mitigation efforts related to liquefaction hazard.

Links are given below for the project reports and tools, including the original 2016 research report, the 2018 addendum report with updated hazard mapping, the SPLiq User's Manual, the SPLiq spreadsheet tool, and the online liquefaction parameter database used with SPLiq. In addition to the project reports and tools listed below, several technical papers were published related to this research.

- TPF-5(296) study webpage https://www.pooledfund.org/Details/Study/538
- UT-16.16 Simplified SPT Liquefaction_Final Rpt_May 2016.PDF https://www.udot.utah.gov/main/uconowner.gf?n=6540219924529800
- UT-18.11 Simplified SPT Liquefaction_Addendum Rpt_Sept 2018.PDF https://www.udot.utah.gov/main/uconowner.gf?n=6539412752487134
- UT-18.10 SPLIQ Users Manual_Sept 2018.PDF https://www.udot.utah.gov/main/uconowner.gf?n=6538918123463124
- SPLIQ version 1.41 https://www.pooledfund.org/Document/Download/8388
- Liquefaction Hazard App, online reference parameter database https://tethys.byu.edu/apps/lfhazard/map/