Research Problem Statement

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I. TITLE

17-067 Design Guidelines for Liquefaction Mitigation using Displacement Piling Ground Improvement

II. PROBLEM

Soil liquefaction is defined as the loss of strength due to seismically-induced excess porewater pressures. Loose, saturated granular materials susceptible to liquefaction are commonly found at bridge locations and present a significant hazard to the transportation infrastructure in Oregon. Our awareness of this hazard has increased with advances in the understanding of the regional seismicity of Oregon, which indicate that the return period of a major Cascadia Subduction Zone earthquake is significantly shorter than previously thought. The ground motions associated with this seismic hazard may even cause dense soils to liquefy under certain conditions. Bridges and approach embankments constructed for new or widened infrastructure must meet current AASHTO standards for maintenance of life-safety following seismic events. Engineers employ various ground improvement programs to alter the in-situ susceptibility to prevent or reduce the effects of liquefaction and subsequent effects on infrastructure performance. Geotechnical engineers typically resort to the use of stone columns (SC; ground densification) or deep soil mixing/jet grouting (DSM/JG; ground reinforcement) to stiffen liquefaction susceptible soils. However, these approaches require the use of imported materials that range from crushed aggregate to Portland concrete cement, materials that require a significant disturbance to the natural environment, due to the mining and processing activities associated with their preparation, impose a significant carbon footprint, and are largely non-renewable. For example, SC and DSM/JG may be disqualified due to environmental impacts in sensitive estuarine deposits that pose significant liquefaction hazards, as was the case at the recent Millport Slough Replacement Bridge project along Highway 101.

Research on driven displacement piling for ground improvement conducted by Oregon State University and sponsored by the Transportation Research Board Idea Program under NCHRP-180 (Stuedlein and Gianella 2015, Gianella et al. 2015) was recently concluded. The findings, based on full-scale tests and controlled blasting, verified the suitability of driven displacement piling as a ground improvement alternative. The benefit of this ground improvement alternative is that both the densification and reinforcement modes of improvement are realized; additionally, driven piles have significantly greater tensile resistance than the DSM or JG alternatives. However, there are no design guidelines available for the application of this approach for liquefaction and lateral spreading mitigation, with design issues that range from quantifying the change in site response caused by the densification and reinforcement to the selection of appropriate design parameters of densified soils and pile reinforcement for use in 2D limit equilibrium analyses. This research is proposed to extend the results of the TRB study using simulation techniques and develop specific design guidelines for the application of driven displacement piles for ground improvement.

III. PROPOSED RESEARCH, DEVELOPMENT, OR TECHNICAL TRANSFER ACTIVITY

Design engineers evaluate the seismic stability of approach embankments and bridge abutments using 2D limit equilibrium (slope stability) methods. This requires careful consideration for the modeling of ground improvement, which takes the form of a three-dimensional geometry. Presently, no design methods or guidelines have been verified and validated for use with displacement piling ground improvement. Appropriate design analyses for displacement piling ground improvement will require the assessment and adaptation of design methods developed for SC (densification and weak reinforcement) and DSM (strong reinforcement). In order to make the leap from design methods for established ground improvement to displacement piling, the following steps are required: (1) develop and validate sophisticated numerical models (e.g., FLAC) that have been calibrated to the data from full-scale test results (e.g., generation and dissipation of excess pore pressure, post-shaking deformations, etc.) previously conducted as part of NCHRP 180; (2) use the calibrated numerical model to perform nonlinear effective stress site response analyses and deformation analyses of typical ODOT bridge approach embankments and abutments (after consultation with ODOT bridge engineers); (3) determine what steps are necessary to replicate the sophisticated numerical analyses using common 2D slope stability analyses (e.g., 3D to 2D conversion of soil and pile properties, selection of horizontal acceleration coefficients, etc.); (4) conduct parametric slope stability analyses to determine which parameters are most critical for optimization of ground

improvement methodologies, and (5) condense the work in (1) through (4) to formalize specific design guidelines for the application of driven displacement pile ground improvement for use with transportation infrastructure.

IV. POTENTIAL BENEFITS

The State of Oregon has recognized that its critical infrastructure is subject to significant seismic risks. Development and implementation of cost-effective liquefaction and lateral spread mitigation strategies serves all roadway users and taxpayers in the State of Oregon. Incorporation of renewable liquefaction mitigation strategies (e.g., if timber piling is used) will benefit the State of Oregon by addressing a critical concern for its new and reparable transportation infrastructure. By using green construction materials – grown in-state and supporting the timber industry – ODOT can address its ability to maintain important lifelines following an earthquake, save lives by improving collapse prevention, and provide a rapid post-earthquake economic recovery.

V. IMPLEMENTATION

The product of this research, design guidelines of displacement piling ground improvement, will be implemented in ODOT bridge design standards. Following review and approval by the ODOT Research and Bridge groups, this work will be used by ODOT bridge engineers and its engineering consultants. Jan Six, Senior Geotechnical Engineer, ODOT Bridge Engineering Section, and Bernie Kleutsch, Region 2 Tech Center Manager, will support the implementation of these guidelines within ODOT.

VI. LIST OF REFERENCES

Gianella, T.N., Stuedlein, A.W., and Canivan, G.J. (2015) "Densification of Liquefiable Soils using Driven Timber Piles," *Proc., 6th Int. Conf. on Earthquake Geotech. Eng.*, Christchurch, New Zealand, 1 – 4 November, 2015, 9 pp.

Stuedlein, A.W. and Gianella, T.N. (2015) "Drained Timber Pile Ground Improvement for Liquefaction Mitigation," *IDEA Program Final Report, NCHRP 180*, Transportation Research Board, The National Academies, Washington, D.C., 59 pp. *(Under final review)*

VII. CONTACT INFORMATION

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