Examining the Geotechnical Earthquake Hazard to Transportation Assets in Oregon and Washington: Characterizing Earthquake-Induced Deformations of Silt Soils

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Center Name: Pacific Northwest Transportation Consortium (PacTrans)

Research Priority: Improving the Mobility of People and Goods

Principal Investigator(s): Diane Moug (PSU)

Project Partners: NA

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Project Description: Although current engineering practice has methods to estimate earthquake-induced deformations for sand and clay soils, there is little guidance for assessing the geotechnical earthquake hazard for other soil types. This is a particular challenge in Oregon and Washington, where soils intermediate to sands and clays (i.e., silts) are prolific throughout the Willamette Valley, including beneath the I-5 interstate bridge, the Puget Sound area, and at Port of Portland facilities. Research is needed to characterize the geotechnical earthquake hazard of silt soils. Geotechnical earthquake hazards include liquefaction, where earthquake loading generates considerable excess porewater pressures and significant strength loss in sand-like soils, and cyclic softening, the fatigue-like strength loss of clay-like soils. Liquefaction can induce large lateral ground movements and/or settlements, which have caused bridge failures, foundation failures, and road embankment failures. Similarly, cyclic softening can cause foundation failures and lateral ground movements. A significant knowledge gap in silt soils is understanding their susceptibility to either liquefaction or cyclic softening and the likely hazard from earthquake loading. Characterizing the geotechnical earthquake hazards will impact engineering practice and transportation seismic risk assessment in Oregon and Washington and other seismic regions with silt soils (e.g., British Columbia, Alaska, New Zealand, and Turkey).

Soils can undergo large deformations and strength loss when subjected to strong earthquake shaking. Current engineering practice has established guidance for estimating earthquake hazards for clay and sand soils. However, there is a lack of knowledge regarding silt soils, which are prolific throughout Oregon and Washington. Excess porewater pressures (i.e., r_u) are produced during earthquake soil loading. If r_u are large enough, liquefaction will be triggered where the soil drastically loses strength. Even if liquefaction is not triggered, severe soil deformations and loss of strength can. This experimental program will test the hypothesis that the earthquake hazard for silt soils relates to r_u and plasticity.

US DOT Priorities: This research project supports the U.S. DOT strategic goal of Economic Strength and Global Competitiveness, and the priorities of Resilient Supply Chains and Advanced Asset Management. Transportation infrastructure including bridges, roads, and ports have been significantly damaged by earthquake shaking and geotechnical earthquake-related ground failures, causing disruptions to supply chains and movement of people and goods. Designing new infrastructure or retrofits to existing infrastructure with the aim that the infrastructure is resilient through natural hazards, specifically earthquake events, requires an understanding of the geotechnical earthquake hazard (i.e., how much ground deformation may be induced by earthquake shaking). This project will provide knowledge and relationships for geotechnical engineers to assess geotechnical seismic hazards of new and existing infrastructure in areas with fine-grained soils.

This project engages in advanced research to expand the current state of knowledge on the earthquake geotechnical hazard of fine-grained soils. Current engineering approaches are primarily based on case histories and laboratory testing of sands, leaving large knowledge gaps for the engineering of fine-grained soils. Specialized laboratory testing on controlled fine-grained soil mixtures will constrain strength loss and deformation due to earthquake shaking.

Outputs: An outcome of this project will be engineering relationships to estimate ground settlement over a range of typical fine-grained soil properties. Such a relationship will inform the expected settlement of overlying structures following an earthquake. Another outcome will be the expected strength reduction of soil due to earthquake loading over a range of fine-grained soil properties. This will be used to estimate post-earthquake structural foundation capacity and lateral deformation of underlying soil. Both relationships will be useful for evaluating the performance of bridges, roads, or ports.

Outcomes/Impacts: This outcomes of this research will be integrated into the seismic assessment or design engineering stages of infrastructure engineering. A better understanding of the geotechnical seismic hazard will improve the reliability and durability of infrastructure, and potentially reduce geotechnical investigation costs at the design and assessment stage or reduce costly overconservative design and ground improvement. The results of this research will be transferred to engineers in the Pacific Northwest through publications, brownbag lunches and presentations at professional meetings or conferences. The research outcomes can also inform regional-level hazard assessment of ground deformation potential and analysis of post-earthquake functionality of transportation infrastructure in the Pacific Northwest, enabling better-informed emergency preparation and response planning.

Final Research Report: *will provide upon completion of the project*