Oregon Department of Transportation

Research Stage 1 Problem Statement
Number 26-32 – "Combining Superstructure Inertial and Lateral Spreading Loads for Geotechnical and Bridge Seismic Resilient Design"

1. Concisely describe the **transportation issue** (including problems, improvements, or untested solutions) that Oregon needs to research.

Proposed Title: Design Guidelines for Bridge Pile Foundations Subjected to Combined Inertial and Liquefaction-Induced Lateral Spreading Loads

Soil liquefaction during earthquakes can result in significant displacements in sloping ground, referred to as 'lateral spreading.' This phenomenon poses a substantial hazard to numerous bridges crossing rivers and streams in Oregon. Both AASHTO Design Specifications and the ODOT Geotechnical Design Manual (GDM) provide considerable flexibility in addressing liquefaction in the design process. While large projects like the Abernethy Bridge allow for the exploration of creative solutions, ODOT undertakes the construction or rehabilitation of many smaller bridges annually, often with much smaller scopes (e.g., typically single-span bridges with a length < 300 ft.). Despite their smaller scale, these projects share similar susceptibility to liquefaction and lateral spreading due to their subsurface conditions. The objective in this research is to improve the design methods applied to address the effects of liquefaction and lateral spreading for these numerous, smaller bridge projects.

2. What **final product or information** needs to be produced to enable this research to be implemented?

The primary outcome of this research includes load factors for combining superstructure inertial and lateral spreading loads in a pseudo-static analysis. The findings from our prior research at PSU, addressing the effects of long-duration motion on inertia and lateral spreading load factors, have been incorporated into the 2022 BC Supplement to the Canadian Bridge Design Code S6:19. This approach follows a similar approach adopted by WSDOT, where the load factors are dependent on seismic contribution factors. We propose a similar approach for ODOT, wherein inertia and lateral spreading load factors are dependent on seismic contribution factors. In our view, this is a technically sound approach that will enhance safety in Western Oregon, where seismic contributions are dominated by long-duration motions, and reduce potential overconservatism in Eastern Oregon, where seismicity is primarily influenced by shallow crustal faults.

The proposed methodology for combining superstructure inertial and lateral spreading loads in a pseudo-static analysis will be detailed in a practice-ready recommended amendment to the ODOT Geotechnical Design Manual (GDM) and ODOT Bridge Design Manual (BDM).

3. (Optional) Are there any individuals in Oregon who will be instrumental to the success of implementing any solution that is identified by this research? If so, please list them below.

Name	Title	Email	Phone
Albert Nako	Seismic Standards Engineer	Albert.NAKO@odot.oregon.gov	971-283-5558
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4. Decision making lenses

Please complete the following three sections. Your answers to these questions will be applied on a programmatic basis to support agency decisions. Answering yes to the questions below is not required. Resolving a narrowly focused technical research problem may meet agency needs without answering yes to any of the following questions. The ODOT Research Section will seek a balanced portfolio some projects will answer yes to one of the three categories below (e.g. climate, equity, and/ or safety) and other projects in a different category.

We are looking for an overall program balance and no one project is expected to balance all categories. Generally, a research problem statement is expected to be able to answer yes with clear and verifiable information in only one of the three categories below, some projects may be able to answer yes in two or even three categories. Some projects (i.e. needs focused on specific elements of infrastructure design), may have no yes answers but may still be high value research need.

Climate

Oregon recognizes the climate crisis and makes systemic changes to reduce emissions caused by travel. Every mile driven in Oregon is powered by a clean source of fuel. We seek research that supports construction and maintenance operations are carbon neutral and investments in mobility that support travel by low and no emission modes. While every research project may not result in a reduction in emissions, transportation investments overall support emission reductions to achieve state goals. Oregon envisions a transportation system that is resilient in the face of seismic and climate events and impacts to the degradation of the natural environment are reduced. Our vision includes a transportation infrastructure is built in a way that avoids impacts on key habitat and results in better environmental conditions for wildlife and native vegetation. For definitions and details please review the equity vision, goals, and objectives of the ODOT Strategic Action Plan and Oregon Transportation Plan.

4f. Will addressing the **transportation issue** identified as a need in Question 1 develop, or validate methods for the estimation, measurement, or monitoring of transportation generated greenhouse gasses (GHG)?

☐Yes ☒No ☐Unsure

4g. If climate or GHG is not the focus of this **transportation issue** identified in this problem statement, will the research apply a GHG analysis to transportation infrastructure, planning, operations, maintenance, or materials?

☐Yes ☒No ☐Unsure

4h. Will the addressing the **transportation issue** include development or testing of construction practices, methods, or materials to establish potential reductions in greenhouse gas emissions?

☐Yes ☒No ☐Unsure

4i. Will the solving the **transportation issue** in question 1 study or support the reduction of vehicle miles traveled and single occupancy vehicle travel or support transition to electric vehicles (or other types of zero emission vehicles) or low-carbon alternative fuels?

☐Yes ☒No ☐Unsure

4j. Will the solving the **transportation issue** in question 1 lead to work that will support, measure, monitor, transportation system resilience in response to expected climate events, effects, or natural disasters in general?

☒Yes ☐No ☐Unsure

4k. Will the solving the **transportation issue** in question 1 lead to work that may result in better environmental conditions for wildlife and native vegetation ?

☐Yes ☒No ☐Unsure

4l. If you answered yes to any of the climate questions above or can provide alternative details related to climate, please provide additional information:

The transportation issue that will be addressed in this study will improve seismic resilience of the transportation system (reference to "natural disaster" in Question 4j above).

Equity

Equity can have many dimensions and impacts relating to communities, and transportation. It is important that problem statement proposals clearly explain in what capacities are equity dimensions or impacts being examined within problem statements. It is a goal of the OTP to "Improve access to safe and affordable transportation for all, recognizing the unmet mobility needs of people who have been systemically excluded and underserved. Create an equitable and transparent engagement and communications decision-making structure that builds public trust". Proposed research may have the intent of studying elements of this goal or apply analysis to specific transportation topics to ensure the resulting research recommendations is consistent with our equity goals. For definitions and details please review the equity vision, goals, and objectives of the ODOT Strategic Action Plan and Oregon Transportation Plan.

4a Is the **transportation issue** identified as a need in Question 1 specifically focused on transportation equity?

☐Yes ☒No ☐Unsure

4b If the **transportation issue** is not focused on transportation equity, will the primary topic be assessed for equity benefits or impacts within the research project?

☐Yes ☒No ☐Unsure

4c Is the implementation of potential findings from this research likely to directly involve participation from an identified group that would benefit from an equitable process or outcome?

☐Yes ☒No ☐Unsure

4d Is the intended final product or information expected to support ODOT's equity efforts (Including but not limited to supporting one of the equity related objectives of the ODOT's Strategic Action Plan or Oregon Transportation Plan) ?

☒Yes ☐No ☐Unsure

4e If you answered yes to any of the equity questions above or can provide alternative details related to equity, please provide additional information:

This research will further support ODOT's ongoing initiatives to establish a more equitable transportation network. Our research at PSU indicates that bridge foundations in the Oregon Coast may be more susceptible to damage from lateral spreading, especially because seismic activity in these areas is dominated by the Cascadia Subduction Zone capable of generating long-duration ground motions. These routes often traverse tribal lands or High Disparity areas as identified by the ODOT Social Equity map. Ensuring the reliability of lifeline routes in the Oregon Coast that remain operational after large earthquakes is not only crucial for fostering an equitable transportation system but also constitutes a vital component of a resilient transportation network for the entire state of Oregon.

Safety
Research outcomes may include interventions and countermeasures to prevent or reduce the frequency of crashes or other causes of transportation-related injury or death; or may include measures to reduce severity of injury (including prevention of death) after a crash or other injurious event. For definitions and details please review the equity vision, goals, and objectives of the ODOT Strategic Action Plan, Oregon Transportation Safety Action Plan and Oregon Transportation Plan.

4m. Will solving the **transportation issue** in question 1 support improving **safety culture** for either transportation workers or the traveling public?

☐Yes ☒No ☐Unsure

4n. Will the solving the **transportation issue** support improving safety through **healthy and livable communities**?

☐Yes ☒No ☐Unsure

4o. Will solving the **transportation issue** support improving safety through using **best available technologies**?

☒Yes ☐No ☐Unsure

4p. Will solving the **transportation issue** support improving safety through **communication and collaboration**?

☐Yes ☒No ☐Unsure

4q. Will the solving the **transportation issue** support improving safety through **investing strategically**?

☐Yes ☒No ☐Unsure

4r. If you answered yes to any of the safety questions above or can provide alternative details related to safety, please provide additional information:

The proposed research will directly address the Safety and Mobility research focus areas. A 2021 study by DHS (Oregon Transportation Systems Regional Resilience Assessment Program) found that liquefaction constitutes the primary cause of severe damage to 989 bridges in Oregon (18% of state-owned bridges) following a Cascadia Subduction Zone earthquake, with reopening times of up to 2.5 years for bridges over waterways or impassable topography. The challenge facing ODOT lies in the fact that ground improvement methods for liquefaction mitigation can sometimes be cost-prohibitive. This research aims to enable ODOT to accurately remove some of the 989 bridges from a high-level concern by potentially demonstrating that their foundations exhibit satisfactory seismic performance without requiring ground

improvement. This approach will allow ODOT to concentrate on a smaller subset of bridges for liquefaction mitigation, leading to increased confidence in the performance of bridges affected by liquefaction issues.

5. Other comments:

The objectives in this research can be effectively achieved using numerical models that are calibrated to already available data from physical experiments on bridge foundations, including shake table tests and case studies. Two baseline numerical models are proposed to be developed, each representing distinct characteristics that are important to capture in this study:

- Model 1: This model will represent a single intermediate bridge bent. It will be constructed based on a 1-g shake table test conducted at UC San Diego by Professor Ahmed Elgamal and Dr. Ahmed Ebeido. The test involved a single 0.25-m diameter reinforced concrete pile shaft supporting a superstructure mass and subjected to 0.4 m of lateral spreading (Fig. 1a).
- Model 2: This model will represent the global response of a full bridge. It will be developed based on a case study conducted by Dr. Ben Turner, Professor Scott Brandenberg, and Professor Jon Stewart of UCLA on a highway bridge in Baja California, Mexico. The bridge experienced 4.6 m of lateral spreading displacement in the free field during the 2010 El Mayor-Cucapah earthquake (Fig. 1b). The foundations of this bridge consisted of four 1.2-m diameter extended pile shafts.

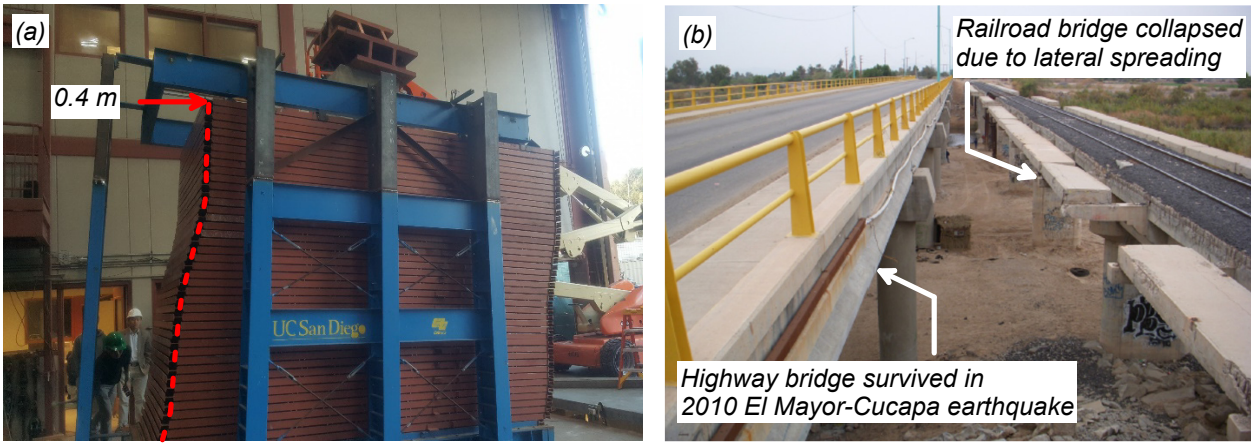

Figure 1. (a) 1-g shake table test for calibration of Model 1 (photo courtesy of Prof. Ahmed Elgamal, UC San Diego), (b) highway bridge in Baja Calif., Mexico for calibration of Model 2 (photo courtesy of Dr. Ben Turner)

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