SPR RESEARCH PROGRAM
SECOND-STAGE PROPOSAL SUMMARY

PROBLEM NUMBER AND TITLE

24-07 Bridge Column Footing Performance and Seismic Retrofit Evaluation Considering Soil-Structure Interaction—Phase II-Field Testing

PROBLEM SUMMARY

Hundreds of older bridges in Oregon are supported on seismically deficient reinforced concrete columns and foundations. To prevent bridge collapses and ensure expedient disaster response and recovery after an earthquake, deficient columns and foundations require retrofits. Recent ODOT funded research has led to the development of a seismic retrofit solution for columns using titanium alloy bars that produced predictable response with high ductility and large energy dissipation. As part of this same study, the influence of the foundation on the retrofitted column performance was also investigated. In these tests, the influence of soil and piles on the column response was significant. This has practical and important ramifications for retrofit designs. Understanding SSI will help assure desired seismic performance of retrofitted substructures.

ODOT OBJECTIVES

This research is intended to complete work begun as part of SPR-830. Due to the impacts of COVID-19 on supply-chain and personnel working conditions, the original project has not been fully executed as planned. The objective of this project is to complete the field testing of aged-in-place footing-column systems constructed as part of SPR-830 and finish validating the developed analytical design approach and evaluation matrix, for incorporation into the ODOT BDDM and GDM. This will further enable development of footing retrofit designs that may be necessary when bridge columns are retrofitted.

BENEFITS

This research addresses seismically-deficient bridges in Oregon and the need to develop design strategies for cost-effective retrofits to their substructures and improved decision support tools. Limited resources require that methodologies that can take advantage of soil-structure interaction, where warranted, be used to extend the life of existing bridges, and that tools be developed to quickly assess whether retrofit of bridge substructures is preferable over replacement given the existing structural details, substructure type, and soil conditions. Incorporation of soil-structure interaction may also show that retrofit or replacement of the substructure is not necessary.

SCHEDULE, BUDGET, AND AGENCY SUPPORT

Estimated Project Length: 18 months.
Estimated Project Budget: $144,000
ODOT Support:
Tanarat Potisuk, Pre-stressed Concrete Standards Engineer, Tanarat.POTISUK@odot.oregon.gov
Albert Nako, Seismic Standards Engineer, Albert.NAKO@odot.state.or.us
Susan C. Ortiz, Senior Geotechnical Engineer, Susan.C.ORTIZ@odot.oregon.gov

FOR MORE INFORMATION

For additional detail, please see the complete STAGE 2 RESEARCH PROBLEM STATEMENT online at:
https://www.oregon.gov/odot/Programs/ResearchDocuments/24-03.pdf

SPR RESEARCH PROGRAM
SECOND-STAGE PROBLEM STATEMENT
FY 2024

PROBLEM NUMBER AND TITLE

24-07 Bridge Column Footing Performance and Seismic Retrofit Evaluation Considering Soil-Structure Interaction—Phase II-Field Testing

RESEARCH PROBLEM STATEMENT

Hundreds of older bridges in the Oregon bridge inventory are supported on seismically deficient reinforced concrete substructures. The substructure includes the supporting columns and foundations. Two types of foundations are commonly found in the inventory: spread footings and timber pile supported pile caps. The columns and foundations were not designed to resist the forces produced during an earthquake. As a result, they lack adequate reinforcing details. These substructure components are expected to perform poorly during a seismic event. To prevent bridge collapses and ensure expedient disaster response and recovery after an earthquake, deficient substructure elements require retrofits. Recent ODOT funded research has led to the development of a seismic retrofit solution for columns using titanium alloy bars that produced predictable response with high ductility and large energy dissipation when the foundation is considered rigid (typical structural assumption). As part of this same study, the influence of the foundation on the retrofitted column performance was also investigated for spread footing with simulated "soil" and for timber pile supported cap. In these tests, the influence of the "soil"/piles on the column response was significant. Soil-structure interactions (SSI) produced rocking response that increased overall system drifts and reduced the moment gradient along the column height. This has practical and important ramifications for retrofit designs. SSI can be both beneficial and deleterious across different criteria and improvements in understanding are needed to ensure desired seismic performance of retrofit-ted substructures.

RESEARCH OBJECTIVES

The research to be conducted in SPR-830 included a comprehensive suite of tasks intended to evaluate the role of various soil support conditions on the response of vintage substructures. A significant task included the development of an analytical design approach and corresponding design matrix for retrofit or replacement of vintage substructures, validated using full-scale bridge substructures tested in representative natural soils. Due to the impacts of COVID-19 on supply-chain and personnel working conditions, the finalization of the design matrix and experimental validation thereof has not been fully executed as was intended. The objective of this project is to complete the field testing of aged-in-place foundation-column systems constructed as part of SPR-830 and validate the developed analytical design approach and evaluation matrix. The intent being to incorporate them into the ODOT BDDM and GDM. It further enables development of footing retrofit designs and their refinements that may be necessary when bridge columns are retrofitted.

WORK TASKS, COST ESTIMATE AND DURATION

The research program proposed to accomplish the objectives consists of the following tasks:

Task 1: Test full-scale, in-situ bridge column-footing specimens. Two vintage, instrumented column-footing specimens have been constructed at the OSU Geotechnical Engineering Field Research Site as part of SPR-830. These specimens will be tested incrementally using snapback and quasi-static cyclic loading tests in their vintage and retrofitted conditions under the wettest conditions, for which we expect soil failure and little damage to the structural specimens, and then under the driest conditions, which will result in significant changes in the SSI response. Test data will be interpreted and compared to the performance established for the 10 structural laboratory test specimens tested in SPR 830.

Task 2: Validate design approaches and corresponding decision matrix for retrofit vs. replacement. Following review of the new and previously-developed experimental and numerical data, and discussions with the TAC, appropriate design guidelines will be developed to capture the salient aspects of SSI on seismic performance of vintage and retrofitted column-footings bearing on moisture-sensitive soils. The design guidelines will be placed within a decision matrix so that the typical ODOT engineer can quickly determine the best option for the retrofit or replacement of a given bridge in the inventory. The structural (strut-and-tie type) model for the footing forces and moments developed in SPR-830 to enable evaluation of demands on footings and facilitate design of footing retrofits will be validated against the results of Task 1.

Task 3: Reporting and Implementation. Document research methodology, findings, and recommendations in final report and assist ODOT in the incorporation of the recommendations into the ODOT BDDM and GDM.

Key Deliverables: The deliverables for this project are well defined, as this is a completion of an existing project. The main objective is the completion of the in-ground testing of full-scale specimens and the analysis of the results with its integration into the analysis of the previously completed work. A strut-and-tie type model for the footing forces and moments will be included. A report of the complete effort will document the results and include a decision matrix for retrofit versus replacement decision making.

Estimated Project Length: 18 months.
Estimated Project Budget: $144,000

IMPLEMENTATION
This new technology will be transferred through presentations given in meetings and workshops with ODOT personnel. Findings will be summarized in technical reports, conference proceedings, journal papers, and will be distilled into improved evaluation and design guidelines. These design guidelines will be implemented in ODOT bridge design standards (BDDM & GDM). Following review and approval by the ODOT TAC, this work will be used by ODOT bridge engineers and its engineering consultants.

POTENTIAL BENEFITS
This research addresses seismically-deficient bridges in the Oregon bridge inventory and the need for developing sufficient design strategies for cost-effective retrofits to their substructures and improved decision support tools. Limited resources require that methodologies that can take advantage of soil-structure interaction, where warranted, be used to extend the life of existing bridges, and that tools be developed to quickly assess whether retrofit of bridge substructures is preferable over replacement given the existing structural details, substructure type, and soil conditions. Incorporation of soil-structure interaction may also show that retrofit or replacement of the substructure is not necessary. Given the number of bridges for which retrofit/replacement is considered desirable, the impact to both budget and project delivery could be significant, with significant potential implications for improving the seismic resilience of the State transportation infrastructure network.

PEOPLE
ODOT champion(s):
Tanarat Potisuk, Pre-stressed Concrete Standards Engineer, Tanarat.POTISUK@odot.oregon.gov
Albert Nako, Seismic Standards Engineer, Albert.NAKO@odot.state.or.us
Susan C. Ortiz, Senior Geotechnical Engineer, Susan.C.ORTIZ@odot.oregon.gov

Problem Statement Contributors: Matthew Mabey, Armin Stuedlein, Christopher Higgins

STAFF REVIEW PAGE

Literature Check

TRID&RIP

☒ A review of TRID & RIP databases found no existing research that answers the research question

Technology & Data assessment

☒ No Identified T&D output

☐ At the end of this project, the implementing unit(s) within ODOT will need to coordinate the adoption of new technology or data in order to realize the full potential of this research.

Cross-agency stakeholders

- List stakeholders or impacted units

Tanarat Potisuk, PhD, PE, SE	Pre-stressed Concrete Standards Engineer
Tanarat.POTISUK@odot.oregon.gov	971-283-5600
Albert Nako, PE	Seismic Standards Engineer
Albert.NAKO@odot.state.or.us	971-283-5558
Susan C. Ortiz, PE, GE	Senior Geotechnical Engineer
Susan.C.ORTIZ@odot.oregon.gov	503-986-3377

By extension, all ODOT geotechnical and structural engineers

- Identify any issues of concern raised by an ODOT stakeholder. Note expected mitigation

None