Research Problem Statement

ODOT Research Section
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I. TITLE

17-024 Foundation Rocking as Part of Seismic Bridge Retrofit for Subduction Zone Earthquakes

II. PROBLEM

One of the major costs associated with implementing a seismic bridge retrofit is addressing the existing bridge bent foundations. In the conventional design approach, rigidity is imposed, uplift prevented and all inelastic behavior forced into the columns. The implementation usually requires exposing the sides of the existing footing, driving new piles around the perimeter, thickening and/or widening of the footing and mechanically tying the new to the existing. The resulting footings become strong and rigid, but are very expensive due to the extensive construction mobilization at the bent locations. This retrofit method may not always be necessary.

An alternative approach is to permit limited movement and allow the columns and foundations to rock during the earthquake. Rocking means that while part of the foundation is in bearing, the opposite side can lift up. This approach has a significantly lower cost of implementation. Rocking enables a smaller construction footprint since does not require foundation widening or additional piles. The consequence in terms of seismic response is that the bents exhibit lower effective stiffness and the soil under the foundation could plastically deform due to the localized stresses. While the economic benefits are substantial, limited guidance exists for bridge engineers to determine when rocking could be beneficial and what potential limits or drawbacks exist regarding the overall bridge performance. The performance related questions are further heightened by the anticipated Cascadia Subduction Zone earthquake, because of the long duration associated with subduction events.

The goals of the research are to quantify the seismic performance of typical Oregon bridges where rocking was utilized as part of the retrofit strategy and develop appropriate design guidance for bridge engineers.

III. PROPOSED RESEARCH, DEVELOPMENT, OR TECHNICAL TRANSFER ACTIVITY

Most research to date has been dealing with stability and settlement of rocking single columns. The major findings have been promising in that columns that rock do not necessarily result in instability or large residual displacements, exhibit lower structural damage in the column, but can have larger vertical settlement as compared to fixed-based cases (Deng and Kutter 2012, Loli et al. 2014, Antonellis et al. 2014). Research is lacking in evaluating the performance of multicolumn bents, which dominate the bridge inventory in Oregon. Numerical models will be developed and subjected to non-linear analyses in order to evaluate the seismic performance of the bent and ultimately of the bridge. Potentially influential parameters (geotechnical and structural) will be selected and their impact on the bridge performance investigated.

Complementary laboratory experiments will be conducted on components to evaluate the performance of the typical as-built column/foundation details. In Oregon, these consist of a columns spliced to a square concrete block foundation that is detailed with a single layer reinforcing at the bottom for gravity loads only. Spread footing as well as piles with inadequate embedment, which in Oregon often consist of 6” embedment and lack any mechanical connections, will be considered in developing the test matrix.

IV. POTENTIAL BENEFITS

Oregon’s bridge inventory consists of older bridges designed with limited considerations of the current earthquake hazard. This results in a statewide need for seismic retrofit to achieve a resilient highway network.

Given the limited financial resources available, cost effective retrofit measures are needed for meaningful impact on the entire network. Designers working on a small portion of bridge retrofits in Oregon have already hinted at the potential cost benefits if limited foundation rocking can be incorporated into seismic design.

The benefits to the state of Oregon impact mobility and provide cost savings. With potentially lower intrusion needed for bent retrofit, traffic restrictions for road overpasses and environmental concerns for bridges over waterways could be minimized. Without this research, the cost of seismic retrofit can be significantly higher, impacting ODOT's ability to retrofit as many bridges as needed to maintain a desired level of seismic resilience.

V. IMPLEMENTATION

The research outcomes will form basis for seismic retrofit guidelines and recommendations aimed for implementation in BDDM for bridge designers faced with phase II retrofit projects. Representatives from ODOT Bridge section will be updated on progress and provided interim findings as appropriate. Findings will be presented in appropriate conferences for wider dissemination of the work and in peer-reviewed journals for critical review and long term reference.

VI. LIST OF REFERENCES *(optional)*

Antonellis G, Gavras AG, Panagiotou M, Kutter BL, Sander A, Guerrini G and Fox PJ. (2014). "Shake table test response of large-scale bridge columns supported on rocking shallow foundations." *Proceedings of the 10th National Conference in Earthquake Engineering*, Earthquake Engineering Research Institute, Anchorage, AK.

Deng, L., and Kutter, B. L. (2012). "Characterization of rocking shallow foundations using centrifuge model tests." *Earthquake Engineering and Structural Dynamics*, 41, 1043-1060.

Loli, M., Knappett, J.A., Brown, M.J., Anastasopoulos, I., Gazetas, G. (2014). "Centrifuge modeling of rocking-isolated inelastic RC bridge piers." *Earthquake Engng Struct. Dyn.*, 43(15), 2341-2359.

VII. CONTACT INFORMATION

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