Design Guidance for Liquefaction Impacts to WSDOT Bridges

I. Introduction

A. Purpose

This Instructional Letter provides project design teams at the Washington State Department of Transportation (WSDOT) with design guidance for liquefaction impacts to WSDOT bridges.

B. Background

Recent changes in the national seismic code and new developments in the understanding and science regarding the affects of liquefaction have been implemented in recent project designs and cost estimates. This guidance is issued to provide clarity on the intended design and decision processes to be followed when structural design and related cost estimates on a project are impacted by these new liquefaction considerations.

Liquefaction mitigation is now at the forefront in bridge designs as bridge failures due to liquefaction have occurred in many countries. AASHTO Bridge Design Specifications clearly state that potential liquefaction issues should be addressed in seismic designs.

See also section III.C. for more background information.
C. Duration of this Instructional Letter

This Instructional Letter remains in effect for one year. It may be extended or rescinded in writing by the Chief Engineer, Assistant Secretary of Engineering and Regional Operations. The intention is to include this information in a future revision of the Design Manual M 22-01.

II. Design Guide for Liquefaction Impacts to WSDOT Bridges

A. Balance Project Risks and Program Budget

WSDOT’s Bridge and Structures Office, in collaboration with the Geotechnical Office, evaluates bridge widenings in liquefiable soils and generally recommends appropriate liquefaction mitigation. This evaluation can yield a variety of scenarios for consideration by the project team. This guidance is intended to assist the project team in getting to a project decision that appropriately balances project risks with project and program budget realities.

B. Design Decision-Making Guidance

The following guidance is generally in order of the complexity of the project decision-making, starting with the most straightforward and descending to the more complex.

1. New bridges will be designed to current seismic and liquefaction standards.

2. Bridge widening not requiring new substructure (i.e. does not require a new column) and thus does not require consideration of liquefaction mitigation.

3. Widening that necessitates any new substructure will require a settlement and lateral loading analysis by the WSDOT Bridge and Structures Office in collaboration with the WSDOT Geotechnical Office. This analysis is unique to the conditions at that particular bridge site.
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a. If a bridge has less than 15 years of its service life remaining no liquefaction mitigation is necessary according to FHWA’s guidelines.

b. If the differential settlement induced by liquefaction between the existing bridge and the widened portion does not create forces great enough to cause collapse of the existing bridge, and if lateral loading and movement caused by the liquefaction is minimal, liquefaction mitigation may not be necessary from a bridge design viewpoint. The final decision and the rationale for that decision will be included in the Design File for that project. The final decision must be endorsed by the State Geotechnical Engineer, the State Bridge Engineer, and the Regional Administrator.

c. If the settlement induced by liquefaction on the existing bridge or if lateral loading and movement is substantial and these movements will result in the collapse of the existing and widened portion of the bridge, additional analysis and documentation is necessary in order for the project to proceed. A preliminary design and estimate of the mitigation necessary to prevent collapse needs to be performed. Alternative designs should be considered that eliminate or reduce the need for the widening.

C. Requirements to Defer Liquefaction Mitigation

1. Consideration of deferment

If an alternative design concept is not feasible given the constraints of the project or program, (e.g. funding, schedule, etc.) consideration may be given to defer the liquefaction mitigation. Project related structural retrofits that are deferred because of scope related issues, are to be considered for implementation through the WSDOT seismic retrofit program. As stated previously, the operating characteristics of the roadway and the overall estimated cost of the liquefaction mitigation is typically considered in making that decision.
2. Deferment requires approval

A decision to defer the mitigation to the seismic retrofit program is made by the WSDOT Chief Engineer after reviewing and considering the merits of alternatives and disadvantages. That decision is to be included in the project Design File. A memo will also be provided from the Chief Engineer to the structural designer of record documenting the agency’s decision to defer the mitigation work to the WSDOT seismic retrofit program. A copy of this memo shall be included in the project’s design file and the contract’s general notes.

III. Additional Information

A. References

WSDOT Geotechnical Design Manual, M46-03
http://www.wsdot.wa.gov/Publications/Manuals/M46-03.htm


B. Contacts

For more information, please contact:

- Tony Allen, State Geotechnical Engineer
- Jugesh Kapur, State Bridge Engineer

C. More Background Information

WSDOT’s liquefaction bridge design policy adheres to AASHTO specifications and policies that allow bridges to sustain extensive damage without total collapse. When soil liquefies it turns into a quicksand like material and loses its ability to support design loads. When the soil is in a liquefied state, it can settle vertically, and also move laterally down the most gentle of slopes. Potential bridge damage due to liquefaction is dependent on the duration and intensity of an earthquake. Bridges built on liquefiable soils are susceptible to plunging failure if the foundations are founded within the
liquefied soil, or to being pushed laterally by the soil flowing down slope. The liquefaction risk reduces substantially in eastern Washington since earthquake intensity in this seismic region is much lower than in western Washington.

The Department of Natural Resources (DNR) has identified areas that have a potential to liquefy within Washington State. These liquefaction areas have been loaded into WSDOT GIS maps. The WSDOT Geotechnical Office is developing GIS maps that show the location of bridges within moderate to high liquefaction areas. In the Puget Sound area, these maps depict the hazard is highest in areas along the entire length of SR 167, sections of I-405, isolated pockets along I-5 and I-90.

Bridges constructed prior to the early 1980s were not required by AASHTO, nor were structures generally designed to resist liquefaction. Based on the new knowledge regarding soil liquefaction, these older designs are less able to withstand settlement and have an increased potential of collapse (defined as a major change in the geometry of the bridge rendering it unfit for use) if the soil liquefies during a seismic event. Initial estimates show about 650 bridges built prior to 1985 are in areas that have the potential for liquefaction. As part of future roadway improvement projects, widening of some of these bridges is planned in the near future.

To determine the amount of settlement and the potential for the soil to flow laterally during the design level earthquake due to liquefaction, a WSDOT Geotechnical Office analysis is needed for each bridge project site location. The information and details collected will be used by Bridge Engineers to determine the bridge’s capability to withstand the movement and loading in a seismic event, and to explore other foundation mitigation options not necessitating total bridge replacement.

To mitigate liquefaction risks for new bridges, bridge foundations are designed to extend past the liquefiable soil layers into more competent soils. Other mitigation techniques that could be used on existing bridges include soil remediation such as jet grouting, the addition of stone columns, or the addition of micropiles.

Prior to the first publication of the WSDOT’s Geotechnical Design Manual in September 2005, our liquefaction design policy was carried out on a case by case basis in consultation with the bridge and geotechnical offices. In some bridge widening projects, the existing and the new bridge portion were both stabilized to resist liquefaction and prevent collapse during a seismic event.
IV. Assistant Secretary of Engineering and Regional Operations

The Assistant Secretary of Engineering and Regional Operations is responsible for periodic review and updates to this document. All executives are responsible for informing the Assistant Secretary of Engineering and Regional Operations of changes needed for the maintenance of this document.

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