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Research Notes

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Project Title:
Development of Liquefaction
Design Guidance for Bridge Foundations

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Assessing Numerical Liquefaction-induced Ground Deformations and Loading Mechanisms

Numerical Assessment of Liquefaction-Induced Ground Deformations and Displacement Demands on Bridge Foundations

WHAT IS THE NEED?

Current techniques for the assessment of liquefaction and lateral spreading consequences are based on analytical simplifications and idealizations that potentially result in widespread variation in lateral spread displacement demands. This high uncertainty has resulted in significant additional expense and/or disruption of bridge design/construction schedules. Presence of the bridge foundations may also have a critical effect on the surrounding ground response, liquefaction process, and overall deformation outcomes.

As such, calibrated mechanics-based computational procedures are needed in order to develop more accurate and reliable design guidelines and practical analysis tools. Salient features of the commonly encountered stratified site conditions need to be addressed using effective stress site response analyses. Of particular concern is the uncertainty in determining the extent of liquefiable soil or the particular soil stratum contributing to the dominant lateral spread zone during an earthquake. This can best be determined using effective stress site response analysis to establish zones or strata first triggering liquefaction, and the associated ground deformations.

WHAT ARE WE DOING?

In North America and elsewhere worldwide, mechanics-based computational tools are being increasingly utilized to analyze soil and soil-foundation-structural systems (Sikorsky 2014). Lateral spread numerical effective stress site response models consist of two major components:

(a) evaluation of time histories of pore-water pressure to determine the particular stratum where liquefaction is first triggered during an earthquake

(b) evaluation of post liquefaction lateral spread displacements associated with sloping ground or bridge embankments, which include potential post-liquefaction strain hardening.

Assessment of stratified site ground seismic response by nonlinear site response computational codes has been underway with continued enhancement over the years. Examples include the DESRA-MUSC program (Qiu 1998) with its high fidelity pore-pressure generation model, and the CYCLIC/OpenSees model (Yang et al. 2003, Elgamal and Lu 2009). Inclusion of such procedures within a multi-dimensional fully-coupled effective stress analysis tool will permit more realistic assessments of ground deformations and the resulting loads imposed on the foundation system.

The following broad tasks are envisioned to accomplish the above.

1. Evaluate and calibrate effective stress site response programs to predict liquefaction triggering in stratified sites and associated ground deformations. Of critical importance are issues such modeling of excess pore-pressure generation (e.g., following the DESRA-MUSC and the CYCLIC/OpenSees models), and cyclic accumulation of deformations.

2. Based on the above work, develop and conduct 2D simulations to more formally include the effects of embankment slopes and the imposed driving shear stresses.

3. Include 2D models of representative pile foundation systems and assess the influence of the piles on reducing the displacement demands, together with the pile curvature ductility demands.

4. Include the impacts of 3D response considerations and the constraints imposed by the overall configuration of the super-structure.

WHAT IS OUR GOAL?

The ultimate goal is the development of design guidance that increases the reliability of liquefaction-induced displacement demands and improves foundation design procedures. In this first task, the improved numerical simulations will be employed to refine the envisioned subsequent experimental phases of this effort (e.g., shake table and centrifuge testing, and laboratory cyclic-load sample testing investigations).

WHAT IS THE BENEFIT?

The final product from this project will be improved bridge design guidance to aid in the design of foundations subjected to liquefaction and lateral spread.

This will reduce the incident verification and response time, resulting in a considerable reduction in delays and congestion associated with freeway incidents.

WHAT IS THE PROGRESS TO DATE?

The wide variance in load demands on bridge foundations using current guidance material has resulted in design schedule delays and increased construction costs. In certain cases, the load demand on the bridge has resulted in total replacement of a bridge, rather than the rehabilitation project initially programmed / budgeted. The improved design guidelines will help reduce costs and schedule delays.