IMPLEMENTATION PLAN NCHRP Project 12-114

GUIDANCE ON SEISMIC SITE RESPONSE ANALYSIS WITH POREWATER PRESSURE GENERATION

DATE: 01/31/23

1. Problem Statement

National Cooperative Highway Research Program (NCHRP) Synthesis 428: Practices and Procedures for Site-Specific Evaluations of Earthquake Ground Motions showed that one-dimensional (1D) equivalent-linear total-stress site response analysis (SRA) is the *de facto* standard for state Department of Transportation (DOT) highway facilities at locations where site-specific ground response analyses are conducted in accordance with provisions in the AASHTO LRFD Bridge Design Specifications (2020) (9th Edition) and the AASHTO Design Guidelines for Seismic Bridge Design (2011). However, many users and various DOTs have concerns about the applicability of equivalent-linear analyses for the cases where site-specific SRA is most relevant (i.e., for soft soil sites, liquefiable sites, and sites subjected to strong ground shaking).

Nonlinear total-stress and nonlinear with excess porewater pressure (PWP) generation and dissipation (i.e., effective-stress) 1D site response analyses are promising alternatives to equivalent-linear analysis. A recent increase in the use of these analyses in engineering practice has been prompted not only by the DOTs' concerns outlined above, but also by the opportunity to reduce spectral accelerations by as much as 33%. There is also a recognition that the use of equivalent-linear analysis at liquefiable sites is not always conservative, especially for long-period structures, like suspension bridges. Also, many bridge engineers practice building-code-based structural design and are cognizant of the requirements imposed by building codes (e.g., requirements of the International Building Code, IBC, 2021 with its current reference standard ASCE/SEI 7-22) to evaluate potentially liquefiable sites by means of effective-stress analysis (ESA). Nevertheless, there are concerns about what types of nonlinear models should be used, the lack of clear parameter selection protocols, the lack of consolidation of lessons learned from validation of effective-stress programs with what has been learned from validation of nonlinear total-stress methods, the lack of 3rd party verification and validation, and the uncertainty with certain interpretations of modeling results.

The purpose of this study (Guidance on Seismic Site Response Analysis with Porewater Pressure Generation) was to develop guidance on the selection of effective-stress numerical models, effective application of 1D ESA, and appropriate interpretation and use of modeling results. This guidance will assist highway facility designers and DOT reviewers to ensure the appropriate use of ESA in engineering practice and may lead to a safer, more economical seismic design for various types of highway facilities.

2. Project Scope and Deliverables

The main objective of this study was to provide guidance on the selection and use of methods for 1D nonlinear seismic site response analysis with excess porewater pressure (PWP) generation and dissipation (effective-stress analysis). A secondary objective of this study is to provide a reference that can serve as a basis for a review of reports submitted to DOTs that base design recommendations upon the results of 1D nonlinear effective-stress SRA.

In general, this study was limited to vertical propagation of horizontally-polarized shear waves (i.e., to 1D analysis; including analysis with 2D software run in 1D mode). It was also limited to nonlinear effective-stress analysis (ESA), as applied to the design of highway bridges and other infrastructure founded in or above potentially liquefiable soils.

Major deliverables developed for this study include a Final Report, which addresses the following topics:

- Site Response Analysis – Overview
- Site Response Analysis – Theoretical Background
- Basis for Development of Guidance
- Research Approach
- Field and Experimental Programs
- Numerical Modeling Program
- Guidance
- Suggested Research

and numerous Appendices, which address the following topics:

- Literature Search
- Field Exploration and Site Characterization
- Experiments and Advanced Laboratory Testing
- Numerical Modeling – Element Tests
- Numerical Modeling – Case Histories

The manuscript of the Final Report (with Appendices) has been submitted to the Transportation Research Board (TRB) of the National Academies of Sciences, Engineering and Medicine (NAS) for publication. Ancillary information (e.g., accelerograms and porewater pressure records) has been posted to DesignSafe (https://www.designsafe-ci.org/) for public availability.

3. Target Audience

In general, users of the Final Report (with Appendices) should be familiar with basic principles of geotechnical earthquake engineering, engineering seismology, engineering geophysics, and structural dynamics. The level of familiarity may vary with the user's role and/or interests (e.g., designer, reviewer, researcher, etc.). Information and guidance presented in the project deliverables is generally targeted toward the following categories:

- Designers: Guidance on how to perform and document effective-stress site response analysis; guidance on how to plan and perform site characterization efforts at potentially liquefiable sites; guidance on how to plan the overall project and how to review the results of numerical modeling and develop recommendations.
- Reviewers: Background information and the explanation of the basic concepts related to site response analysis, including planning and execution of field, validation, and analysis programs.
- Researchers: A wealth of information that can be used for future studies

4. Implementation Tasks

Parties involved in the study's execution and preparation of deliverables included the Research Team (RT), the RT's internal Technical Advisory Panel (TAP), the NCHRP / NAS, and the NCHRP Panel. These parties include a combination of practitioners, researchers, and DOT representatives from both the public and private sectors. Specific implementation tasks for these parties are anticipated to include the following:

- Research Team (and internal TAP): Develop a summary presentation for delivery to transportation professionals at the 2024 TRB Annual Meeting.

- NCHRP / NAS: Publish the Final Report as an NCHRP report; host the Final Report, Appendices, and ancillary information for public access.
- NCHRP Panel Members: Participate in "technology transfer" and promote adoption of Final Report findings in respective domains (e.g., state DOTs, academic research, and professional practice).

5. Potential Constraints on Implementation

Potential constraints on implementation include the following:

- Absence of prospective funding for development of training courses, etc.
- Absence of mechanism for RT to compel adoption of recommendations by DOTs, practitioners, etc.