Harnessing Results of Nonlinear Dynamic Soil Structure Interaction Analysis in Reinforcement Design of an Underground Rail Station

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Abstract

Underground structures located in highly active seismic regions can experience significant earthquake demands. Non-Linear Dynamic Soil Structure Interaction (NLDSSI) analysis using multiple earthquake records is becoming more prevalent method of assessment of those demands and is included in Design Criteria of many American transportation agencies. This paper will explain the advantages and challenges of NLDSSI compared to traditional seismic design methods of underground structures and an example of application on an underground station located in Los Angeles. To deal with the amount of data generated by NLDSSI the design team developed a semi-automated post-processing tool for reinforcement design using LS-Dyna model results, MySQL database, post-processing and custom visualization in Rhinoceros 3D and Grasshopper.

Keywords: Concrete, Underground Structures, Seismic Design and Response, Information Technology, Computational Methods, LS-Dyna

1 Introduction

Non-Linear Dynamic Soil Structure Interaction (NLDSSI) analysis using multiple earthquake records is becoming more prevalent method of assessment of those demands and is included in Design Criteria of many American transportation agencies. However, the amount of design data to be handled in post processing and the actual member design represents a major challenge for structural engineers. In order to avoid overly conservative design, engineers must also adopt new methods of design alongside more sophisticated analysis methods to fully harness their potential.

For one station located in Los Angeles the authors have developed a semi-automated post-processing tool for reinforcement design using LS-Dyna model results, MySQL database, post-processing and custom visualization in Rhinoceros 3D and Grasshopper. Post-processing layer is able to calculate reinforcement demands using fib Model Code 2010 [2] equations for combined in and out of plane forces at each shell element and each time step of the time history analysis. Another suite of tools is then used to average results over a width of a design strip and visualize reinforcement demands in a format ready for drawing production.

This paper will explain the advantages and challenges of NLDSSI compared to traditional seismic design methods of underground structures, individual components of the workflow developed by the design team and the benefits gained from this approach in the design of a light-rail underground station.

1.1 Project Description

The example project is a two story cut and cover station located in Los Angeles. The station is at depth 66 feet (20m) and features a one story crossover which will connect to twin-bored tunnels (see Figure 1). The station's outer concrete box structure consists of 36" (915mm) thick RC walls and 38"-42" (965-1065mm) thick invert and roof slabs.

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