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CALTRANS DIVISION OF RESEARCH, INNOVATION AND SYSTEM INFORMATION
TRANSFORMING IDEAS INTO SOLUTIONS

Research Notes

Development of Design Evaluation Criteria in Performance Based Seismic Design (PBSD) of Cut and Cover Tunnel

Bridge research to establish seismic damage levels in terms of engineering demand parameters (EDPs) for Cut and Cover Tunnel.

Geotechnical/ Structures

MAY 2026

Project Title: Development of Design Evaluation Criteria in Performance Based Seismic Design (PBSD) of Cut and Cover Tunnel

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WHAT IS THE NEED?

In the past, the design of Caltrans tunnel projects solely relied on project specific seismic design criteria. As a result, seismic structural performance varied from project to project. Recent advances in tunnel design have the potential to implement Performance Based Seismic Design (PBSD). PBSD can be used to quantify different seismic damage levels in terms of Engineering Demand Parameters, EDPs (such as ductility demand, drift ratio, and strain), given all possible seismic events. The long-term goal in developing Cut-and-Cover tunnel (CACT) seismic design criteria is to estimate the probability of various damage levels for design life of the structure when subjected to all possible earthquakes and to achieve seismic design uniformity in terms of performance levels. What is needed is to establish experimental based correlation between EDPs, damage levels, and develop a framework for the seismic design of CACT.

WHAT ARE WE DOING?

Caltrans is contracting with University of California, San Diego to investigate the varies damage states of Cut and Cover Tunnel. This research will involve experimental testing and numerical simulation of typical cut and cover tunnel type. Conduct soil-structure-interaction (SSI) analyses and identify critical deformation demands for testing. Perform cyclic pushover tests to capture tunnel deformation and displacement. Identify different damages states in terms of functional limit state and collapse limit state. Conduct post-test model validation and parametric study on influence of

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design parameters. Develop preliminary fragility framework for cut and cover tunnel.

WHAT IS OUR GOAL?

The goals of this project are to establish experimental based correlation between EDPs, damage levels, and develop a framework for preliminary fragility curves for CACT.

WHAT IS THE BENEFIT?

Bridges and tunnels play a critical role in our transportation system in enhancing California mobility and economy. In the past, most of the design efforts are mainly focused on bridge performance. Uniform tunnel design has become increasingly important as we transition to a performance-based design framework in targeting equal risk of structure damage. The benefit of this uniform performance will be increased network reliability and cost efficiency. Like bridge, the quantification of tunnel performance has the added benefit of providing Caltrans and stakeholders critical information for decision making and future planning of California's transportation network.

WHAT IS THE PROGRESS TO DATE?

Finite element models were developed for the prototype RC tunnel linings, and the modeling scheme was validated with experimental data from a tunnel model test. A soil–tunnel model was developed for SSI analyses using the software platform OpenSees. The model accounts for the nonlinear behavior of both the soil and the tunnel lining. The soil was modeled using the Pressure Independent Multi-Yield (PIMY) material model in OpenSees. A numerical study was conducted to investigate the influence of different soil–tunnel system parameters on the racking response of the tunnel lining and the distribution of soil pressure on the lining. The parameters included soil properties, soil depth relative to the bedrock, burial depth of the tunnel, the sequence of soil placement around and above the tunnel lining, backfill properties, tunnel width, and characteristics of the earthquake acceleration records.

The tunnel specimen was fabricated at the UCSD testing lab. The specimen was scaled down by 40% and was constructed according to Caltrans' typical design detailing requirements. The laboratory test setup is currently underway.

Construction of tunnel specimens #1 and #2 has been completed. Observations of specimen damage at the end of each loading cycle have been documented up to 6% drift. The team looked into various case studies on concrete tunnel spalling and reviewed methods to prevent concrete spalling as well as potential mitigation strategies.

IMAGES

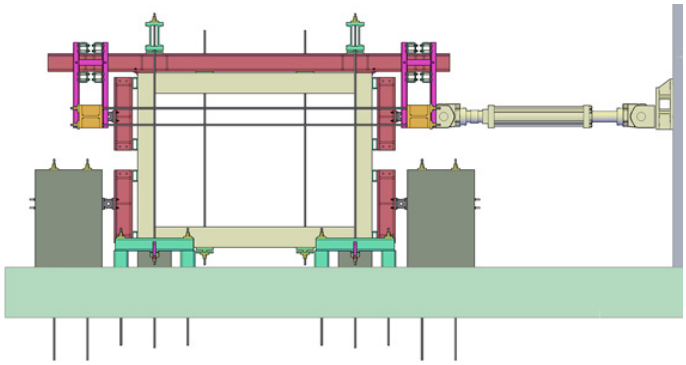

Image 1: Test Setup Overview (Curtesy of UCSD).