DRISI

Caltrans Division of Research, Innovation and System Information

Research Results

Assessment of Cut and Cover Tunnels - Large Scale Tests

Develop insights and design guidelines based on experimentally derived seismic response.

Structure/Seismic

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Project Title:
Seismic Assessment of Cut and Cover Tunnels - Large Scale Tests

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WHAT IS THE NEED?

Cut and cover tunnels are becoming increasingly a preferred solution for transportation challenges in California. Currently, the knowledge base and quantitative data sets concerning seismic response are scarce. With this anticipated and steady increase in construction of such projects, seismic response quantitative data, and calibrated reliable assessment tools and approaches are needed.

The proposed studies aim to ultimately provide experimentally validated engineering procedures for use in the development of cut and cover tunnel seismic assessments (racking considerations) and design guidelines.

WHAT WAS OUR GOAL?

Generally, the goal is to develop insights and design guidelines based on experimentally derived seismic response. For that purpose, an experimental program is needed to address: i) capacity and potential seismically-induced nonlinear deformation mechanisms of the reinforced concrete tunnel liner, and ii) seismic demand as dictated by the input ground shaking excitation and the tunnel-ground interaction mechanisms. In this regard, large-scale testing allows for more accurate representations of the tunnel reinforced concrete liner configuration, and use of field soil materials and construction procedures.

WHAT DID WE DO?

Three test model configurations were employed with different backfill conditions for the surrounding soil and thickness of overburden soil. Two levels of soil compaction were considered in terms of the relative density (Dr, about 99% and 85%). The resulting response in terms of peak racking, wall bending moment, lateral earth pressure resultant force on both sides, and associated location of the resultant forces were documented in model scale. These results were further expressed in the full-scale dimensions.

Both model-scale and full-scale responses of the tunnel in terms of peak racking and wall bending moment were compared to those estimated from the FHWA step-by-step procedure using the peak ground acceleration (PGA) obtained from the tests.

WHAT WAS THE OUTCOME?

From the shake table tests for three test models under different backfill conditions and thickness of overburden soil (tunnel embedment depth), it was noted that maximum tunnel lateral load dictated by racking and wall bending moment correlates with peak ground acceleration. Overburden soil above the tunnel roof was seen to play a role in dictating peak tunnel lateral load and the salient findings (Figure 2) included (for the tested modernconstruction tunnel configuration):

1. With no or little overburden ground, low lateral loads are to be expected even for high peak ground acceleration beyond 1g.
2. Even with significant overburden above the tunnel roof (e.g., in the range of up to 20 ft), lateral loads remained relatively low for peak accelerations of up to 0.5g.
3. For peak accelerations beyond 0.5g and thicker overburden strata, lateral load may increase substantially, associated with a possible level of nonlinear response in the surrounding soil adjacent to the tunnel.
4. For higher overburden soil (e.g., deeper cut-cover tunnels with 10 ft overburden or more), and larger peak accelerations (e.g., 0.6 g and above), a numerical site-specific assessment is recommended.

Racking and wall bending moment were calculated using the FHWA procedure and compared to the test results in model and prototype scale. The following conclusions were drawn from this study:

1. For higher overburden soil depth (e.g., approaching 20 ft), the FHWA procedure results in reasonable estimates of peak lateral moments.
2. With no or little overburden soil (e.g., up to 10 ft), conservatism of the FHWA procedure was quite noticeable.
3. As the earthquake intensity increased (e.g., 0.6 g and above), application of the FHWA procedure tended to be rather sensitive to the backfill material stiffness properties, associated with high levels of shear strain in the surrounding soil adjacent to the tunnel.

WHAT IS THE BENEFIT?

A valuable database of experimental results was generated and archived for the purposes of: i) development of guidelines and design recommendations, ii) value of employing the FHWA procedure prior to performing advanced analyses using the finite element method for instance, and iii) calibration and validation of computational simulation tools.

LEARN MORE

https://www.dropbox.com/s/6e810oyx6g5vr2n/Caltrans%20Final%20Report_v02.pdf?dl=0

IMAGES

Image (a): Model of tunnel structure

Image (b): Tunnel being lowered into large soil container

Image (c): Tunnel inside soil container resting on compacted ground

Image (d): Instrumentation and strain gages on tunnel outer side of tunnel wall

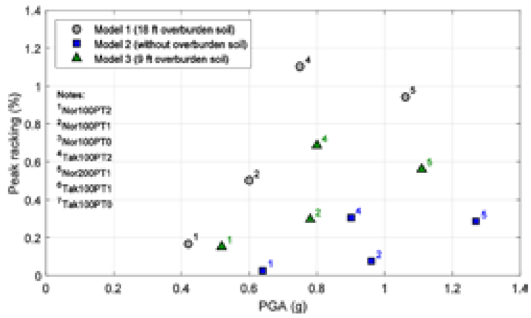

Image (e): Relationship of peak racking with peak ground acceleration in full-scale model dimensions (prototype)