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Research Notes

Seismic Assessment of Cut 'n Cover Tunnels – Large Scale Tests

Complete large scale test plan developed under Phase I (Task #2420)

Geotechnical/ Structures

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Project Title:
Improved LRFD Specifications for California Bridge Design

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WHAT IS THE NEED?

With a significant increase in urban traffic and a lack of open space to build additional surface streets many cities throughout the country are building sub surface shallow road way tunnels. Cut-and-cover tunnels are structural types used for tunnels with relatively shallow earth cover and to also improve the environmental impact of roads and railway lines (noise reduction, better integration in the landscape, continuity of the ground surface).

For seismically active regions, structures need to be designed to resist significant ground motions. The seismic response of the underground structure is governed by larger deformation and inertial responses of surrounding soil. Thus, the design of these structures to withstand the seismic loading has different aspects from the seismic design of above ground structures. Seismic behavior of tunnels is defined by Owen and Scholl (1981) in terms of three types of deformations:

1) Axial compression and extension where axial deformations in tunnels are induced by components of seismic waves generating motions parallel to the axis of the tunnel and cause alternating compression and tension;

2) Longitudinal bending where bending deformations are caused by the components of the seismic waves that produce particle motions perpendicular to the longitudinal axis; and

3) Ovaling for circular tunnels or racking for rectangular tunnels, where ovaling or racking deformations are developed by shear waves propagating normal to the tunnel axis and cause a distortion of the tunnel cross-section.

Much research has been done on deep tunnels, mainly in rock, but very little literature is available on the subject of shallow and in this case particularly, very shallow tunnels in soft soils. Within an integrated framework: i) an experimental program will be developed and executed to address the salient seismic response characteristics of the reinforced concrete tunnel structure, and the ground-tunnel soil-structure interaction mechanisms, and ii) on this basis, validated procedures will be established for seismic assessment and design of cut and cover tunnels.

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WHAT ARE WE DOING?

Research to accomplish the above goal will consist of shake table tests, calibration of computational simulation tool and parametric studies; and development of design guidance material. To elaborate on these tasks:

1. Conduct 2 shake-table experiments using a large laminar container at the UCSD outdoor shake table. The input base excitation suite of motions will be defined in consultation with Caltrans, and in accordance with model scaling relationships. Near field and far field-type ground motions will also be considered.

2. Employ before and after computational simulation tools to design the experiments and to develop calibrated and validated assessment tools. Computer codes to be utilized will include OpenSees, two-dimensional plane-strain finite element models, and simpler soil-spring models.

3. Employ the experimentally validated analysis tools to develop seismic assessment and design guidelines for cut and cover tunnels.

WHAT IS OUR GOAL?

The objective of this task is to perform large scale shake table tests, coupled with numerical studies to establish robust seismic design criteria. More specifically, the research plan aims to develop experimentally validated approaches, as a basis for reliable analysis and assessment procedures. With such analysis tools, parametric studies will be conducted towards the development of seismic assessment and design guidelines for cut and cover tunnels.

The final product will be suggested revisions to the Caltrans Seismic Design Criteria (SDC) for cut and cover tunnels.

WHAT IS THE BENEFIT?

Cut and cover tunnels are increasingly a preferred solution for transportation challenges in California. The proposed research will provide calibrated reliable assessment tools and approaches to ensure such structures are designed and constructed in an efficient manner.

WHAT IS THE PROGRESS TO DATE?

The contract was executed in late August (2 months late) due to issues related to insurance coverage for UT.

A data assessment was performed. Eight new load test reports were sent to UTA for evaluation and entry into the database.

Load-deformation curves and driving records were added to the existing database.

An initial resistance factor calibration using the current driven pile database was performed at both UTA and Caltrans. Agreement in results was reached.

Since Caltrans has such little CIDH load tests the PI began a search for other possible datasets that can be used.

It was decided that since the driven pile databse was fairly advanced, a phi factor caibration will be performed first and various methodology issues explored using that dataset. Analysis of the CIDH data will take place in year two.

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