Geotechnical Feasibility Evaluation of State Route 710 Tunnels

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ABSTRACT: The State Route 710 North Study is the culmination of a long history of efforts to alleviate traffic congestion in the Los Angeles area. One of the options being evaluated is a freeway tunnel alternative. The proposed tunnel will be one of the longest and largest highway tunnels in the world, at over 55 feet (16.8 meters) in diameter with lengths ranging from 4.5 to 11 miles (7.2 to 17.7 kilometers). This paper focuses on some of the early considerations for evaluating tunnel corridor options and challenges, the approach implemented for subsurface characterization, and the geotechnical study conducted to identify factors affecting the geotechnical feasibility of the tunnel. The paper discusses various geologic conditions with respect to tunneling design and construction, including variable ground conditions, high groundwater, active faults, high seismicity, contaminated soils and groundwater, and naturally occurring gas.

1. INTRODUCTION

The State Route (SR) 710 North Study is the culmination of a long history of efforts to address north-south mobility and alleviate traffic congestion within a 100-square-mile (260-square-kilometer [km]) area in the Los Angeles Basin in Southern California, USA.

The California Department of Transportation (Caltrans) retained CH2M HILL in 2008 to study all practical routes for extending SR 710 using a tunnel within the study area.

Fig. 1 presents the study area. Based on requests from local communities, the study was to be guided by "route-neutral" principles for the extension of SR 710. Route-neutral means that all routes receive equal attention and that no route for the tunnel is favored over another. As part of the route-neutral concept, Caltrans (along with the CH2M HILL team) identified the five study zones presented in Fig. 1; these zones represent the potential corridors for extending SR 710.

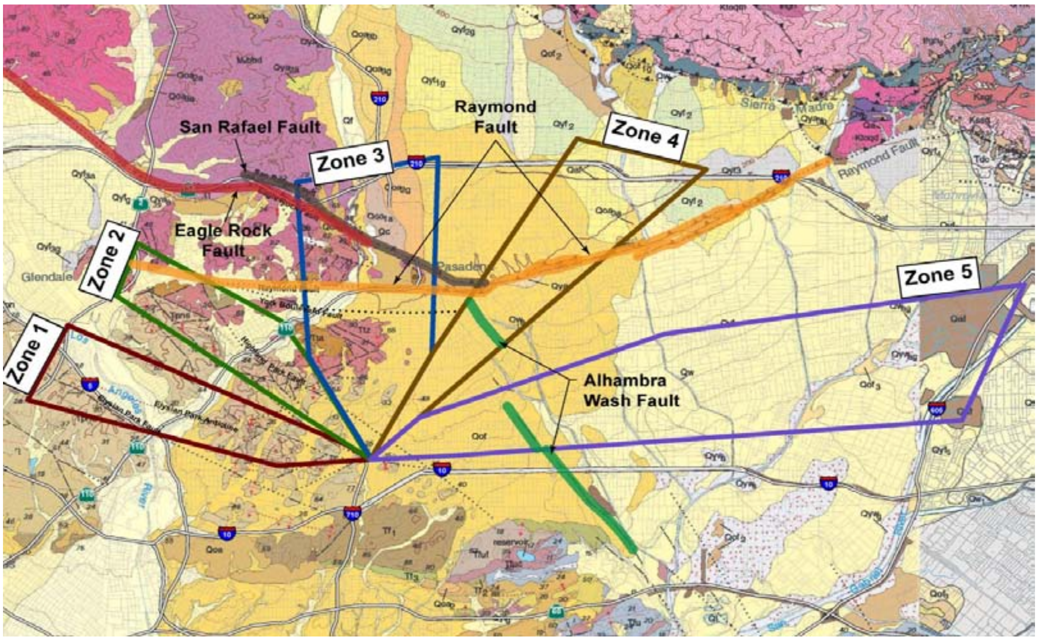

Fig. 1 SR 710 Tunnel Study Area and Zones

The purpose of the geotechnical study was to determine the geologic, groundwater, and seismic conditions within the selected study zones to identify factors that affect the geotechnical feasibility of designing and constructing the proposed tunnel, and to provide a basis for comparison of the geologic conditions with respect to tunnel design and construction. For this study, the invert (bottom) of the tunnel was assumed to be approximately 200 feet (61 meters) below ground surface (bgs). The diameter of the tunnel was assumed to be over 55 feet (16.8 meters). This paper presents a summary of geotechnical considerations and preliminary concepts proposed to address the geologic conditions for the Freeway Tunnel Alternative within the five study zones shown in Fig. 1 (CH2M HILL, 2010).

2. DATA COLLECTION AND FIELD EXPLORATION PROGRAM

The data collection program included a comprehensive compilation and review of reports and publications on surface and subsurface conditions in the five study zones. Historical and recent aerial photographs also were examined to identify topographic and vegetative features indicative of earthquake-induced surface rupture.

The field investigation program included core borings, geological reconnaissance, and geophysical surveys. To characterize subsurface conditions, 32 core borings (with depths ranging from 110 to 500 feet [33.5 to 152.4 meters]), 17 seismic reflection lines, and 78 multichannel analysis of surface wave (MASW) tests were performed. Fig. 2 presents a representative geologic profile developed for Zone 3.

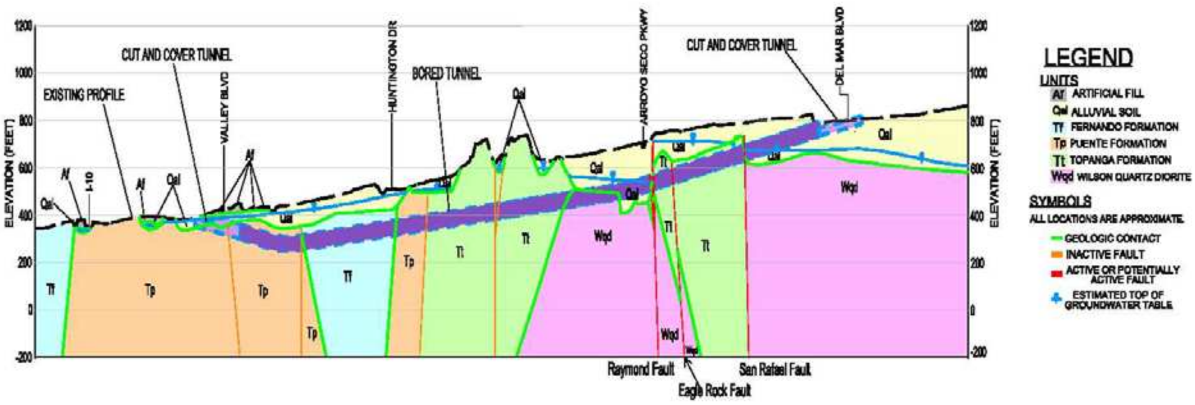

Fig. 2 Representative Geologic Profile, Zone 3

3. GEOTECHNICAL CONSIDERATIONS FOR TUNNEL DESIGN AND CONSTRUCTION

Information collected during the study was interpreted relative to tunnel design and construction within each of the five zones. Zones with similar geology/geotechnical conditions were grouped to provide similar tunnel design and construction considerations. Geotechnical conditions and preliminary concepts to mitigate these geotechnical conditions are described in the following sections.

3.1 Geologic conditions in zones 1 and 2

Tunnel excavations in Zones 1 and 2 are likely to be in the Fernando, Puente, and Topanga Formations, depending on the location of the tunnel through the study zones. These formations consist of sedimentary rocks that have similar tunneling characteristics. Strong cemented layers and concretions may be encountered locally in the Puente Formation. Typically, the formation in Zones 1 and 2 consists mostly of sandstone, siltstone, and shale. The uniformity of geological conditions in Zones 1 and 2 will simplify construction planning. The potential impact of the cemented layers and concretions will need to be addressed in the selection/design of tunnel excavation equipment. These layers may reduce tunnel advance rates; however, properly designed tunneling equipment can successfully excavate these formations.

3.2 Geologic conditions in zone 3

A tunnel through Zone 3 will encounter varied geologic conditions, including unconsolidated soil deposits (alluvium), weak sedimentary rocks (Puente, Fernando, and Topanga Formations), and strong igneous and metamorphic basement complex rocks (Wilson Quartz Diorite) with a wide range of strength and other physical properties. The basement complex rocks in the northern part of the alignment are stronger rocks that would likely require greater effort to excavate than the sedimentary rocks. Fig. 3 presents a photograph of the cores obtained during the study in Zone 3.

Fig. 3 Topanga Formation Cores Obtained During the Study in Zone 3

Although Zone 3 exhibits the most variable geology of all the zones, excavation of a tunnel in this zone could be accomplished with specialized tunneling machines adaptable to the expected range of anticipated geologic conditions, or by using a flexible approach that allows methods to be changed to suit the geology. Because of the variability, the tunnel-boring machine (TBM) could have a cutterhead with tools that can be changed to excavate either soil or rock. Fig. 4 presents a photograph of a pressurized-face TBM equipped with a cutterhead for rock and soil. In addition, pressurized-face excavation methods likely would need to be used for face stability in the alluvium and fractured or faulted rock zones.

Fig. 4 Pressurized-Face TBM Equipped with Cutterhead for Rock and Soil

3.3 Geologic conditions in zones 4 and 5

Subsurface conditions are fairly uniform in Zones 4 and 5 at tunnel depth and consist mainly of Old Alluvium with a limited amount of sedimentary rocks (Fernando and Puente Formations). The Old Alluvium is generally expected to consist of uncemented coarse sand and gravel interbedded with sand, silt, and clay. Cobbles and boulders can be expected locally in the Old Alluvium.

Tunneling through alluvium involves a greater potential for loss of ground at the tunnel face and surface settlement than tunneling through rock. It is expected that the majority of the soil at tunnel depth will be saturated, which increases the potential for instability and surface settlement. Specialized TBMs with positive-face control, using earth-pressure balance (EPB), would be needed.

3.4 Active and inactive faults

Several inactive faults are likely to be encountered within the study area. The active Raymond fault crosses Zone 2 at the northwestern end, Zone 3, and Zone 4. The Raymond fault is capable of generating earthquakes in the range of moment magnitude (Mw) 6 to 6.7 (Weaver and Dolan, 2000), and of producing displacement of about 1.6 feet (0.5 meter) at tunnel depth. The potentially active San Rafael and Eagle Rock faults cross Zone 3.

The Alhambra Wash fault is considered active and projects into Zones 4 and 5. It is capable of generating earthquakes in the range of Mw 6 to 6.25. The potential surface rupture displacement along the Alhambra Wash fault would be expected to be much less than those anticipated along the Raymond fault.

Tunneling across earthquake faults in Zones 2, 3, 4, and 5 is expected to include excavation in fractured rock, clay gouge, and variable groundwater conditions. The groundwater head can vary considerably across a fault if it is acting as a groundwater barrier. For example, the difference in groundwater head across the Raymond fault is about 100 feet. Therefore, the potential for groundwater inflows could be expected to vary dramatically across a fault zone. Potential for groundwater inflows can be controlled by using pressurized-face TBMs and watertight lining for the tunnel. A tunnel crossing a fault could encounter a wider zone of faulting if the tunnel were to cross the trend of the fault obliquely. A properly designed TBM can normally excavate these fault crossings without major difficulty, although the rate of excavation is normally less than the rate in better-quality (i.e., unfaulted) rock.

Special considerations will need to be made for excavating through a fault, and lining a tunnel in an active fault zone. Typically, an oversized tunnel can be excavated in a fault zone with an oversized lining constructed, which would accommodate the large fault offset as expected for the Raymond fault. Steel segmental lining may be feasible for a smaller fault displacement, as expected for the San Rafael and Alhambra Wash faults.

3.5 Contaminated soil and groundwater

The contaminated soil and groundwater sites in Zones 1, 4, and 5 have the potential to impact tunnel construction and muck-disposal operations. In particular, plumes of contaminated groundwater and soil could be encountered during tunnel excavation. Although the severity of the hazardous conditions might be less in a tunnel than on the ground surface, handling hazardous materials in the confinement of a tunnel could be challenging. The contaminated soil, water, and vapors must be controlled to protect workers and avoid contaminating adjacent areas. The contaminated soil and water must be handled properly and be transported to appropriate disposal sites.

3.6 Naturally occurring gas

Naturally occurring gas (methane and/or hydrogen sulfide) could be encountered in any of the formations discussed previously. However, based on experience with other tunnels in Los Angeles, naturally occurring gas is most likely to be encountered within the Puente Formation. This formation is present in all five zones in different proportions. Appropriate precautions will be necessary in accordance with California Occupational Safety and Health Administration requirements for dealing with naturally occurring gases during tunnel excavation.

4. CONCLUSIONS

An approach was developed for comparing the significance of the geotechnical conditions in each study zone. The significance of the geotechnical conditions was determined by evaluating two factors. The first factor considers the likelihood of a certain issue or condition being encountered; the second considers the impact or consequence of the issue or condition if it is encountered. The likelihood of occurrence of key factors was used to assess the significance and potential impact of a certain geotechnical condition. Table 1 shows whether the issue/condition has low, moderate, or high significance based on the qualitative assessment of each of the factors considered in the analysis.

Additionally, each geotechnical condition has been categorized as design-, construction-, or operation-related. This classification is independent of how significant the issue is; however, it assists in identifying the phase or phases of the project that each condition pertains to most. The results of the evaluation summarizing the comparative analyses are presented in Table 1.

Based on the information collected and reviewed as part of the geotechnical study, tunneling is considered to be geotechnically feasible in all five zones, provided appropriate tunneling technology is used to account for expected soil conditions.

Table 1. Summary of Significance of Geotechnical Conditions by Zone

Zone	Variable Ground Conditions	Unstable Soils	Active/ Potentially Active Fault Crossings	Groundwater Conditions	Gassy Conditions	Contaminated Soil and/or Groundwater
1	Low	Moderate	Low	Low	High	Low
2	Low	Low	Low	Low	High	Low
3	Moderate	Moderate	Low	Low	Moderate	Low
4	Moderate	High	Low	Moderate	Low	Moderate
5	Moderate	High	Low	High	Low	Moderate
Type*	D, C	D, C	D, C, O	D, C, O	C, O	D, C

*Type of Geotechnical Condition: Design (D), Construction (C), Operational (O)

REFERENCES

CH2M HILL (2010). Final Geotechnical Summary Report, SR 710 Tunnel Technical Study, Los Angeles County, California, April.

Weaver, K.D., Dolan, J.F. (2000). Paleoseismology and Geomorphology of the Raymond Fault, Los Angeles, Bulletin of the Seismological Society of America. v. 90, p. 1409–1429.