

Previous Tunneling Experience

12.1 Local Tunneling Experience

This section summarizes some local tunneling projects constructed in geologic conditions similar to the various zones being considered for the SR-710 Tunnel. These local projects include the NEIS, the ECIS, and the Metro Red Line and Gold Line Eastside Extension. The NEIS tunnel is located in and south of Zone 1 and other tunnels are located south of Zone 1. Histories from these tunnels provide information about tunneling in similar geology as well as lessons learned from challenges encountered and overcome in the previous projects. Figure 12-1 shows these local projects in relation to the SR-710 study area.



Figure 12-1. Approximate Location of Local Tunnels in Relation to SR-710 Study Area
Background image source: GoogleEarth.

12.1.1 Northeast Interceptor Sewer

Project Description. The NEIS is part of a sewer system that provides hydraulic relief for the existing North Outfall Sewer (NOS), located in the northeast communities of Los Angeles. The tunnel has an excavated diameter of 13 feet and is 5.3 miles in length. The finished diameter of the tunnel is just under 8 feet. Construction was completed in 2005, and the tunnel is currently in operation (Zernich et al., 2005).

Geologic Conditions. The NEIS tunnel was excavated through alluvial soils and weak sedimentary rock with up to 3 bars of groundwater pressure. The weak sedimentary rock encountered in the NEIS tunnel was predominantly Puente Formation with shorter reaches of Fernando Formation and Old Alluvium. The Puente Formation consisted of claystone, weak sandstone, and strongly cemented sandstone. Photographs of the Puente Formation are shown in Figure 12-2. The Old Alluvium consisted mostly of very dense sands with silt and clay with occasional boulders and cobbles. The ground cover above the tunnel ranged from approximately 70 to 140 feet along the alignment.

Tunneling Methods and Construction Observations. Due to the weak rock, saturated soil deposits, and high groundwater pressures, the NEIS contract required the use of three TBMs – two EPB TBMs and one hard rock TBM. The EPB TBMs were specified for the soft ground reaches to maintain excavation stability, control loss of ground, and avoid surface settlement. Because the tunnels were constructed underneath the groundwater table, watertight ground support, consisting of gasketed precast concrete segments, was installed as the initial support. Watertight construction methods were also used to excavate the shafts. Four large work shafts used for TBM launch and retrieval were constructed using slurry walls.

The NEIS alignment traverses a region well known for naturally occurring petroleum hydrocarbons, and it was expected that high concentrations of methane and hydrogen sulfide were to be encountered along the entire tunnel drive. The tunnels were all classified by Cal-OSHA Division of Mines and Tunnels as “gassy” due to the presence of methane and hydrogen sulfide concentrations. During tunneling procedures, operations were stopped when gas concentrations exceeded the allowable threshold. The problems were mitigated by installing fans in strategic locations to ensure that there were no areas of stagnant air. This allowed adequate quantities of fresh air to be introduced near the heading so that the dilution of the toxic and combustible gases occurred. Additionally, sodium percarbonate was added to a sump area to help with degradation of hydrogen sulfide (Dubnewych et al., 2005).

Relevance to SR-710 Project: Tunneling conditions in some of the zones of the SR-710 tunnel are expected to be in similar geology as the NEIS tunnel (that is, the Puente Formation in Zones 1 through 5 and Fernando Formation in Zones 3 and 4). The Upper Reach of the NEIS alignment crosses the western portion of Zone 1, and the Puente Formation is the same formation that is expected in many of the zones for the SR-710 tunnel. A watertight lining similar to the one used in the NEIS tunnel will likely be needed for the SR-710 tunnel. Additionally, the naturally occurring gas that was encountered in the NEIS project could possibly be expected in Zones 1 through 5 of the SR-710 Tunnel Technical Study.



Figure 12-2. Exposed Face of Puente Formation encountered--when excavating a connector tunnel for a future sewer tie-in on the NEIS project (top). Shaft excavation in the Puente Formation--on the NEIS project (bottom).

12.1.2 East Central Interceptor Sewer

Project Description: The East Central Interceptor Sewer (ECIS) is an approximately 11.4-mile-long sewer tunnel that runs from Culver City to East Los Angeles. This tunnel is part of the same sewer system as the aforementioned NEIS tunnel. The excavated diameter of the tunnel was approximately 15.4 feet. The finished diameter of the tunnel is approximately 11 feet. Construction was completed in 2004, and the tunnel is currently in operation.

Geologic Conditions: This tunnel was excavated entirely in alluvium and marine sediments. Approximately 80 percent of the tunnel was excavated in the Lakewood Formation (Old Alluvium), which typically consists of dense silty sands and sandy silts with occasional gravel, cobbles, and boulders (Critchfield and Miya, 2004). A photograph of the muck generated while tunneling through the Lakewood Formation is shown in Figure 12-3. Approximately 10 to 15 percent of the tunnel was excavated in the hard silts and clays of the San Pedro Formation, and the remaining 5 to 10 percent of the excavation was through recent alluvium, consisting of loose to dense, silty, and sandy soils with gravel, cobbles, and boulders. The depth-to-tunnel invert generally ranges from 30 to 100 feet; however, it is as much as 360 feet in the area where the alignment goes under the Blair Hills.

Tunneling Methods and Construction Observations: ECIS was driven in five separate tunnel drives by four EPB TBMs. Each of these TBMs was identical – four were used simultaneously to meet schedule concerns. Tunneling in this urban environment requires a higher degree of ground loss control than other areas. EPB machines were specified for use on the ECIS to mitigate ground loss, surface settlement, and damage to existing structures. Additionally, construction monitoring – consisting of surface surveys, muck volume monitoring, and muck testing – occurred continuously during mining (Seeley, 2004). Ground treatment after tunneling was performed if needed based on the analysis.

While these machines and techniques generally achieved the goal of no surface disruption, there were instances of overexcavation. Unintended ground loss occurred during machine stoppages for cutterhead maintenance, especially in uncemented sands. This challenge can be overcome by a machine design which allows human entry to the cutterhead while maintaining control of the tunnel face. The initial lining of the tunnel was a precast concrete segmental liner. As in the NEIS tunnel, hydrogen sulfide and methane gases were encountered during the excavation. Additionally, contaminated soils were encountered at some locations along the alignment (Critchfield and Miya, 2004).

Relevance to SR-710 Project: Tunneling through the recent alluvium and the Old Alluvium (Lakewood Formation) will likely be similar to some of the tunneling conditions in the alluvial soils expected in Zones 4 and 5 of the SR-710 tunnel. Ground loss and surface settlement can be mitigated not only with strict specifications and construction monitoring but also because there have been machine improvements since ECIS. A watertight lining similar to the one used in the NEIS tunnel will likely be needed for the SR-710 tunnel if constructed in these zones. Additionally, naturally occurring gas and contaminated soils were encountered in ECIS, and the same is expected in Zones 1 through 5 for the SR-710 tunnel.



Figure 12-3. Alluvium of the Lakewood Formation, with cobbles, falling off a conveyor during excavation of the ECIS Tunnel.

12.1.3 Los Angeles Metro Red Line Project

Project Description: The Metro Red Line extends from Downtown Los Angeles (Union Station) to the community of North Hollywood in the San Fernando Valley. This twin-bore tunnel system was built in three different segments at different times. Segment 1 extends from Union Station to the west along Wilshire Boulevard. The middle segment – known as Segment 2 – extends from the Wilshire/Vermont Station to the Hollywood/Highland Station. Segment 2 runs north-south along Vermont Avenue and east-west along Hollywood Boulevard. The third Segment runs from the Hollywood/Highland Station north through the Hollywood Hills to the San Fernando Valley and is called Segment 3. The two bores are connected with cross passages and have excavated and finished diameters of approximately 22 feet and 18 feet, respectively.

Geologic Conditions: Segment 1 was excavated through both the Fernando Formation and Los Angeles River alluvial deposits. The Fernando Formation consisted of well-stratified claystone and siltstone with significant cohesive strength (Robinson et al., 1989). The alluvium consisted of firm to very stiff silts and clays, and medium-dense to very dense sands (Robinson and Wardwell, 1991).

The section of tunnel underneath Vermont Avenue (Segment 2) was excavated almost entirely in the Puente Formation. The lithology of the Puente Formation encountered was predominantly stratified and interbedded claystone and siltstone with harder sandstone

beds. The Hollywood Boulevard tunnel section of Segment 2 was excavated predominantly in alluvium (Gordon et al., 1995). The depth of ground cover over the tunnels ranged from 20 to 161 feet in this section of the excavation.

Segment 3 was excavated through shale and sandstone of the Topanga Formation, the Simi Conglomerate, as well as intact to fractured granodiorite with fault gouge in the Santa Monica Mountains (Kramer et al., 1998). In the San Fernando Valley, the tunnel was excavated through young and Old Alluvium and the Topanga formation. The young and Old Alluvium consisted of dense and stiff sands and clays, and the Topanga Formation was generally well-cemented siltstone, sandstone, and claystone.

Tunneling Methods and Construction Observations: The headings for Segment 1 were mined with digger shields. Settlement was something that was monitored very closely in this segment because the tunnels were underneath many tall buildings in downtown Los Angeles. In the cohesionless alluvial soils, chemical grouting was used to ensure face control. This chemical grouting was performed after it was realized that compaction grouting under the buildings might not be sufficient to limit settlement, especially in the cohesionless soils (Robinson and Wardwell, 1991). The excavation characteristics of the Fernando Formation were considered firm, with little to no raveling occurring; however slow raveling occurred in the alluvium (Escandon et al., 1989). Additionally, due to the presence of naturally occurring gas, a liner of high-density polyethylene (HDPE) was installed between the initial and final lining to restrict the flow of gases into the tunnel during operation of the subway (Navin, 1991).

All headings for Segment 2 were excavated using digger shields (Gordon et al., 1995). A photograph of a digger shield used for the Red Line is shown in Figure 12-4. During the excavation, both of the sections of tunnels were considered "gassy." Additionally, both contaminated soil and groundwater were anticipated and encountered during the excavation of the tunnels in Segment 2. The Hollywood Boulevard tunnels encountered high groundwater inflows not long after the mining commenced and was subsequently shut down for dewatering, which lasted for many months. Even after dewatering, this section was plagued with groundwater inflow problems, as well as cobbles and boulders that were unforeseen in the alluvium. These groundwater inflows could have been prevented if the tunnels were excavated using a machine with pressurized-face technology.

The section of Segment 3 through the hard rock of the Santa Monica Mountains was excavated using two rock main-beam TBMs. The crossing of the Hollywood fault is a noteworthy aspect of Segment 3. This is an active thrust fault and the largest active fault that the entire Red Line will cross. A special seismic section was developed consisting of an oversized sacrificial vault section with a special lining. The lining for this section consisted of steel-fiber reinforced shotcrete and lattice girders, and it was mined using the New Austrian Tunneling Method (NATM) techniques (Albino et al., 1999). After completing the vault, the concrete segmental lining was erected in the tunnel and the annular space between the vault and the segmental lining backfilled with a compressible material. If there is offset in this fault trace, the vault section will be displaced and the movement dissipated within the compressible material, keeping the segmental lining and the tunnel intact and serviceable although the tracks may need to be realigned.

Relevance to SR-710 Project: Many aspects of the Los Angeles Metro Red Line will be similar to those of the proposed SR-710 tunnel, depending on the alignment chosen. Both tunnels are twin-bore transit tunnels with cross passages and excavation in a very urban environment. The SR-710 tunnel will likely go under occupied buildings for which settlement and ground loss would need to be designed. Also, the SR-710 tunnel passes through active faults in Zones 3 through 5 and would need a special seismic design for the lining through those fault zones, such as the oversized excavation used in the Metro Red Line fault crossing or other methods. The geology has the potential to be quite varied (hard and soft rock, and alluvium) in Zone 3 of the SR-710 as it was along the many segments of the Metro Red Line. And, as mentioned for many of the projects in the Los Angeles area, the potential for naturally occurring gas (in Zones 1 through 5) or other contaminants (in Zones 1, 4, and 5) is expected in the SR-710 tunnel as it was encountered for the Metro Red Line tunnels.



Figure 12-4. Digger Shield used in Los Angeles Metro Red Line Tunnel.

12.1.4 Los Angeles Metro Gold Line Eastside Extension Project

Project Description: The Metro Gold Line East Side Extension Project consists of 6 miles of new light rail and eight new metro stations. Approximately 1.7 miles of this alignment include a twin bore of 21.5-foot (excavated diameter) tunnels (Robinson and Bragard, 2007). There are six cross passages that connect the two bores. This extension project originates in downtown Los Angeles at Union Station and continues to serve areas east of downtown, crossing underneath several existing structures in this urban environment. The tunnel excavation began in 2005 and is now complete.

Geologic Conditions: The soils encountered in this project were Old and Young Alluvium—the majority of the excavation in Old Alluvium. The Old Alluvium is composed of loose to very dense sand and gravel with varying amounts of stiff clay and silt, as well as cobbles and occasional boulders. Generally, the Old Alluvium was denser than the young alluvium (Choueiry et al., 2007). The majority of the tunnel was excavated under the groundwater level, which reached a high of about 13 feet above the invert in the middle of the tunnel alignment. The ground cover was as shallow as 35 feet in some areas along the alignment.

Tunneling Methods and Construction Observations: The tunnels were excavated using two EPB TBMs, and the two tunnels were mined approximately 40 feet apart, from center to center. Figure 12-5 is a photograph of one of the TBMs being launched. At certain locations along the alignment, the cover was as little as 35 feet. The six cross passages were mined using sequential excavation methods, consisting of a top heading and bench. According to Robinson and Bragard (2007), the mix of clay and sand was quite good for tunneling— noting that the clayey ground had sufficient sand in it so the muck did not get too sticky, and the sandy ground had the amount of clay needed to give the muck some “body.”

Approximately 220 structures were identified as being within the zone of influence of tunneling. To avoid settlement or differential settlement of any of the buildings, compensation grouting was selected as a “real-time” control over the potential settlement. Grout pipes were directionally drilled beneath the structures of interest, in advance of the tunnel heading. Grouting crews were on standby when a TBM was within 100 feet of a structure to be ready to perform compensation grouting if settlement reached the action levels specified. The settlement was monitored by using small reflectors stationed on the roof corners of targeted buildings. A total station instrument measured the monitors constantly and reported back to engineers who were analyzing the data. Ultimately, no surface settlement reached the action level set forth in the specifications to warrant grouting (Choueiry et al., 2007).

The alignment passed through zones of contaminated soils, and the muck generated from those areas was segregated and transported to an appropriate disposal site. Similar to the NEIS project, this tunnel was considered “gassy” by Cal-OSHA regulations; ventilation was a serious concern due to high levels of methane gas. The maximum advance rate (best day) was 91 feet per day and 95 feet per day for the eastbound and westbound tunnels, respectively.

Relevance to SR-710 Project: Similar geologic conditions (saturated alluvium) that were encountered in the Metro Gold Line East Side Extension Project will likely be encountered in Zones 3 through 5 of the SR-170 tunnel. Also, the presence of contamination (expected in Zones 1, 4, and 5) and naturally occurring gas (expected in Zones 1 through 5) were aspects of the Metro's project that will be encountered in the SR-710 project. Additionally, the Gold Line project was constructed under many occupied buildings, and virtually no surface settlement was allowed. Depending on the zone and alignment chosen for the SR-710 tunnel, it could be constructed similarly under occupied buildings or structures that would not be able to tolerate settlement or angular distortion.



Figure 12-5. TBM Being Launched for the Metro Gold Line Eastside Extension in Los Angeles.

12.2 Recent Large-Diameter Highway Tunnels

In addition to local tunneling projects, information about some large-diameter highway tunnels that have been recently designed and constructed in California and around the world was collected and reviewed. These projects are considered to be relevant to the SR-710 tunnel for the reasons discussed below. Included in the following sections are summaries of the Caldecott Fourth Bore (California, USA), Devil's Slide Tunnels (California, USA), Calle 30 Tunnel (Madrid, Spain), Shanghai Yangtze River Tunnel (Shanghai, China), and SOCATOP A86 Tunnel (Paris, France). This information is not intended to be comprehensive, but the discussion provides some background information relative to large-diameter highway tunnels similar to the SR-710 tunnel.

12.2.1 California

12.2.1.1 Caldecott Fourth Bore Tunnel

Project Description: The Caldecott Fourth Bore Tunnel is a vehicular tunnel along SR-24 that has been designed, with construction expected to begin in late 2009 or early 2010. This tunnel is located in Alameda and Contra Costa counties in Northern California. The owner of the project is Caltrans. This project will increase the number of vehicular lanes in the Caldecott tunnels, which currently consist of three bores. The project will add a 3,400-foot horseshoe-shaped tunnel that is 50 feet wide and 32 feet high with two traffic lanes. Additionally, seven cross passage tunnels between the planned fourth bore and existing third bore will be constructed (Thapa et al., 2007). A rendering of the portal area for the new tunnel can be seen in Figure 12-6.

Geologic Conditions: The tunnel is expected to pass through shale, chert, sandstone, siltstone, claystone, and conglomerate and to cross four major inactive faults. These faults occur at contacts between geologic units. The rock was broken into four ground classes, based on mechanical characteristics and on anticipated ground behavior in response to excavation.

Tunneling Methods and Construction Observations: The tunnel excavation design is based on the sequential excavation method (SEM) consisting of a top heading and bench. Some initial support elements include plain and fiber-reinforced shotcrete, lattice girders, fast-setting cement-grouted rock dowels, fiberglass rock dowels, self-drilling and grouted spiles, injection spiles, and self-drilling grouted pipe spiles. The final lining of the tunnel will be a cast-in-place (CIP), reinforced-concrete lining. A waterproofing membrane with a geotextile backing layer for drainage will be installed between the initial support and the final lining.

Relevance to SR-710 Project: This large-diameter highway tunnel is planned to be excavated in the future in Northern California. Similar to the SR-710 project, Caltrans will be the owner; therefore, many of the design elements will be similar. Additionally, the variable geology is similar to that of Zone 3 of the SR-710 tunnel, and the potential for encountering inactive faults is similar to all zones of the SR-710 tunnel.



Figure 12-6. The Caldecott Fourth Bore Tunnel portal showing the existing tunnels and simulation of the proposed tunnel (highlighted with yellow circle).

12.2.1.2 Devil's Slide Tunnel

Project Description: The Devil's Slide Tunnel is a vehicular tunnel currently under construction. It is located along SR-1 in San Mateo County in Northern California. The owner of the project is Caltrans. The road alignment passes through a pair of approximately 3,950-foot-long tunnels that will run 650 feet beneath San Pedro Mountain. The width and height of the horseshoe-shaped excavation is approximately 36 feet and 27 feet, respectively. The horseshoe shape of the tunnels provides for one lane with a wide emergency shoulder. Ten emergency cross passages will connect the two bores, spaced approximately 400 feet apart. A central cross passageway also provides access for emergency vehicles. At the two portal exits, the tunnels will be enlarged by 8 feet each to provide a turnout lane with extra visibility for maintenance vehicles.

Geologic Conditions: The tunnel will be excavated through granitic rock in the South Reach, sandstone in the Central Reach, and claystone-siltstone, sandy conglomerate including, fine-grained sandstone intervals crushed and sheared to gouge in the North Reach. Three inactive faults divided the mountain geologically. Except for the portal areas, the groundwater table is above the tunnel. Major groundwater migration pathways are fractured fault zones, contact surfaces between different formations, and different materials within the formations.

Tunneling Methods and Construction Observations: Based on the varying and challenging geologic conditions, the NATM technique was selected as the most suitable approach for construction. The advance lengths vary between 3 feet and 7 feet, depending on the geologic conditions. The initial support varied depending on the anticipated geologic conditions. A steel fiber reinforced shotcrete lining in combination with rock dowels provides initial support for the best conditions. A photograph of the shotcreting operation is shown in Figure 12-7. As rock quality degrades, the addition of steel lattice girders and spiles provides improved support. For worse conditions, additional face support measures (long face dowels, core, shotcrete face sealing) and a reinforced shotcrete invert arch are required. The ground conditions for excavation are classified as potentially gassy conditions.

Relevance to SR-710 Project: This highway tunnel is currently being excavated in Northern California for Caltrans. Additionally, the varied geologic conditions and faulting along its alignment are similar to the mixed conditions in Zone 3 of the SR-710 tunnel. Additionally, the crossing of inactive faults and the potential for naturally occurring gas are similar between the tunnels.



Figure 12-7. Shotcreting in the Devil's Slide Tunnel.

12.2.2 Worldwide Experience

12.2.2.1 Calle 30 Tunnel, Madrid

Project Description: The south bypass M-30 twin-tube tunnels in Madrid, Spain, are vehicular tunnels that have an approximate excavated diameter of 49 feet. The tunnels will accommodate cars and heavy trucks and was the only solution for relieving traffic in this heavily congested area. Each bore allows three lanes of vehicular traffic. In addition to the three traffic lanes, each tunnel houses two emergency lanes located beneath the concrete road slab, along with ventilation conduits and other essential facilities. Figure 12-8 shows a schematic of this cross section and the installation of the road deck slab separating the traffic lanes from the emergency access below. The two bores are each approximately 2.2 miles long and are connected with eight cross passages – five passages for emergency pedestrian access and three for emergency vehicular access. A ventilation shaft is also needed for each tube (Fernandez, 2007).

Geologic Conditions: The subsurface conditions consisted of sandy clay and hard clay with gypsum. The maximum hydrostatic pressure that was expected was 6 bar; on average, the maximum overburden ranged from 100 feet to 215 feet. However, at the portals, there was as little as one tunnel diameter of overburden to reduce the depth of the rectangular shafts used to launch the machines.

Tunneling Methods and Construction Observations: The tunnels were excavated using two EPB TBMs, each supplied by a different manufacturer. Some specifications for the TBMs included the ability to work in as high as 6 bars of pressure and avoid horizontal ground loss at the face of the excavation. Additionally, the design specified that boulders up to a size of 28 x 12 x 12 inches needed to be able to fit through the screw conveyor of the EPB machine. To achieve a relatively fast excavation rate and to comply with all of the other specifications of the contract, innovative designs by the TBM manufacturers were submitted.

The lining of this tunnel used 2-foot-thick precast bolted segments in a nine-segment plus key configuration. The average daily advance rate for this tunnel was 60 feet per day, and the maximum advance rate was 151 feet per day (best day of production).

Relevance to SR-710 Project: The TBMs used for this job are some of the largest TBMs ever manufactured. A TBM of this size or a similar size could possibly be necessary to excavate the SR-710 project, depending on the traffic requirements and design of the tunnel cross section. The main similarity between this tunnel and the SR-710 tunnel is the size of the excavation and final use of the tunnel; however, similar geology (soft ground) and groundwater conditions are expected in the SR-710 tunnel as well.

12.2.2.2 Shanghai Yangtze River Tunnel

Project Description: The Shanghai Yangtze River Tunnels are part of a major transportation infrastructure project located at the mouth of the Yangtze River in China. The entire project includes a tunnel, a cable-stayed bridge, and a series of approach roads that total just under 16 miles. The tunnel portion of the project is approximately 4.5 miles. Three lanes of vehicular traffic and one rail line will be provided in each bore of this twin-bore tunnel. Each bore has an excavated diameter of approximately 50.5 feet, and they are spaced approximately 100 feet apart.



Figure 12-8. Roadway slab construction for the Calle 30 tunnel in Madrid (top) Schematic showing the final use of the tunnel (bottom).

Geologic Conditions: The geology along the tunnel excavation is predominantly silty clay with occasional sand and sandy silt layers. The overburden ranges from approximately 20 feet at the TBM launch area to 60 feet, and the majority of the tunnel is excavated underneath the groundwater table (Ferguson et al., 2008).

Tunneling Methods and Construction Observations: Due to the high water pressures, ground conditions, and shallow cover, two slurry TBMs were selected to excavate the tunnels; one is shown in Figure 12-9. To deal with the anticipated 6-bar hydrostatic pressure, the cutterhead arms were outfitted with special facilities to allow changing the cutter tools without entering the pressurized excavation chamber. If the workers had to enter the chamber under 6-bar hydrostatic pressure, mixed gases would have to be used, extending the time needed for tool changes.

Bolted and gasketed precast concrete segments were used as the initial lining of the tunnel. The segments used are approximately 2.1 feet thick and are installed in a nine-segment plus key configuration. The average advance rate for these tunnels was approximately 39 feet per day with the maximum advance rate (best day) of 85 feet per day (*Tunnelbuilder*, 2008).

Relevance to SR-710 Project: Similar to the M-30 tunnel in Madrid, the TBMs used for this project are two of the largest TBMs ever manufactured. The Shanghai Yangtze River Tunnel will have a similar number of traffic lanes as required for the SR-710 tunnel, and the geology and groundwater conditions are similar to the alluvial soils expected in some parts of Zones 3 through 5 of the SR-710 tunnel. The case history of this project can be used to help with planning of the SR-710 project, another large-scale highway tunnel.



Figure 12-9. Largest TBM in the world to date, for the Shanghai Yangtze River Tunnel Project (Herrenknecht, 2009).

12.2.2.3 SOCATOP A-86 Highway Tunnels, Paris

Project Description: The SOCATOP A-86 tunnel is a vehicle tunnel located in the suburbs of Paris, France. The twin-level tunnel is approximately 38 feet in excavated diameter and allows for three lanes of vehicular traffic in each direction. The tunnel is approximately 6.2 miles long with emergency exit shafts every 3,280 feet. Figure 12-10 shows a cross section of the tunnel at a location with an emergency alcove and pressurized shelter.

Geologic Conditions: The tunnel excavation was through extremely variable geological conditions including rock (limestone and chalk) and soils (sands, silts, and clays).

Tunneling Methods and Construction Observations: Due to the mixed conditions along the length of the alignment, a mixed-mode TBM was developed to be able to mine the range of anticipated geological conditions. This machine is capable of operating in EPB or Slurry mode (Fulcher et al. 2006). The machine's configuration can be changed for different types of geology in about 24 hours. Precast concrete segments in a seven-segment plus key arrangement were used to line the tunnel. The average advance rate on this job ranged from about 40 to 46 feet per day.

Relevance to SR-710 Project: The TBM used in this highway tunnel project has been designed to mine through many different types of materials and has a relatively large diameter. Technology such as this could be very useful in mining Zone 3 of the SR-710 tunnel with similarly varied geologic conditions.

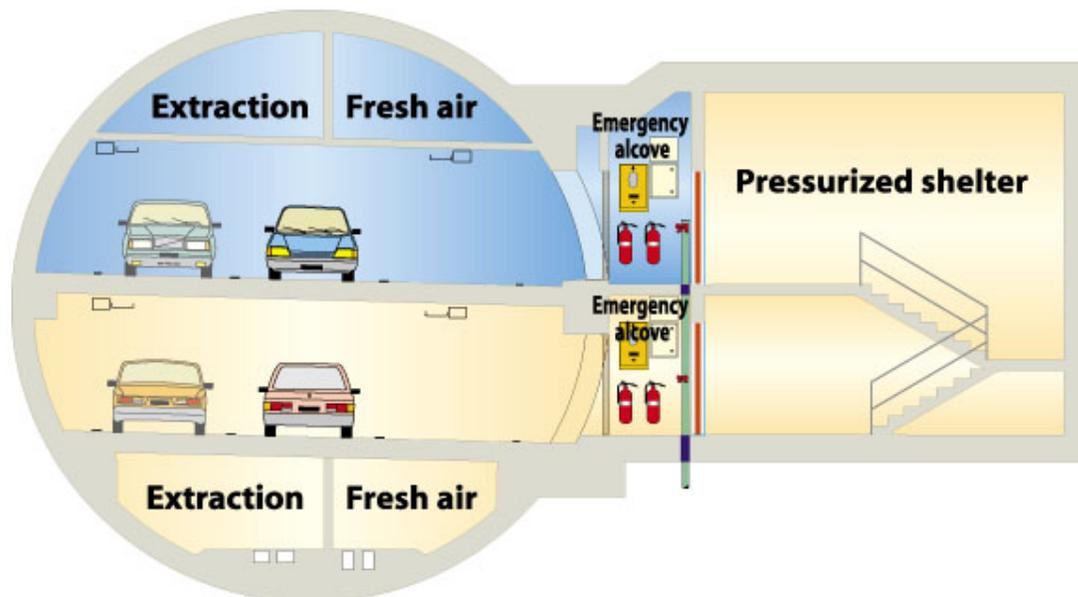


Figure 12-10. Cross Section of SOCATOP A86 Tunnel at Location of Pressurized Refuge Chamber (Cofiroute, 2009).

12.3 Summary of Relevance to SR-710 Project

In the previous sections, case histories of other tunnel projects were discussed. Each of these projects has relevance to the SR-710 project due to similar geologic conditions, construction methods, or both. Table 12-1 summarizes which aspects the SR-710 tunnel would be similar to the aforementioned tunnel projects. Worldwide tunnel projects like the Madrid Calle 30 Tunnel, Shanghai Yangtze River Tunnel, and Paris A-86 Highway Tunnel demonstrate that the technical capability exists for constructing large-diameter highway tunnels (35 to 50 feet) with lengths up to 6 miles. Available technology does not limit the tunnel length that can be constructed as similar tunnels up to 10 miles in length are in the planning stages.

TABLE 12-1
Summary of Case History's Relevance to SR-710 Tunnel

Tunnel Name	Geology	Fault Crossings	Naturally Occurring Gas	Contaminate Soils	Tunnel Size (>35 feet)	Highway Tunnel	Urban Setting	Tunnel Length (>4 miles)
NEIS								
ECIS								
Metro Red Line								
Metro Gold Line								
Caldecott Fourth Bore								
Devil's Slide								
Madrid Calle 30								
Shanghai Yangtze River								
Paris A-86 SOCATOP								

12.4 Similarities between Sewer, Water, and Highway Tunnels

The previous sections detail design and construction aspects of selected tunnels; however, not all of the case histories selected are for highway tunnels such as the SR-710 tunnel. While some permanent features of a tunnel are dependent on its final use, the majority of the aspects of tunnel construction are independent of its final use. Some of the main differences between these different types of tunnels are explained herein.

The first difference is in the shape of the tunnel. Most water and wastewater tunnels are circular, which is the preferred shape for hydraulic reasons. Highway tunnels can be either circular or horseshoe shaped. A horseshoe shape is usually more efficient for highway tunnels in rock. In addition to the shape, another difference is the final lining. In a water or wastewater tunnel, the final lining must provide a durable and smooth interior surface that minimizes hydraulic head losses and controls leakage (exfiltration) from the tunnel. If a water tunnel is pressurized, the final lining must be able to withstand internal water

pressures. Additionally, the final lining of a wastewater tunnel must be corrosion protected from the hydrogen sulfide gases that effluent produces.

Another significant difference between highway tunnels and water and wastewater tunnels is that highway tunnels are occupied facilities with the public traveling through the tunnel. This makes public safety a key issue; thus, the design of appropriate fire-life-safety provisions is a requirement of the project. Water and wastewater tunnels have personnel entering the tunnel only when the tunnels are inspected, typically at 5-year intervals.

All tunnels must adhere to fire-life-safety standards for the workers of the tunnel during construction; however, a highway tunnel must have a permanent fire-life-safety system in place. Some of the safety systems include proper emergency ventilation, fire suppression, communications, refuge areas, emergency exits (to the surface or a cross passage to an adjacent tunnel), and alarms. In addition to the ventilation needed for a fire to clear out harmful chemicals, a highway tunnel needs ventilation under normal operations to eliminate the products of combustion in vehicles traveling through the tunnels. In addition to ventilation, other permanent finishes such as the road deck, lighting, and signage are needed for a highway tunnel that would not be needed in a wastewater or water tunnel.

Additionally, the diameter of highway tunnels is typically much larger than water or wastewater tunnels due to the clearance envelope needed for a lane or multiple lanes of cars and trucks. Highway tunnels are typically about 35 to 50 feet in diameter, whereas most water and wastewater tunnels are less than 20 feet in diameter.

These differences generally have to do with permanent features of the tunnel; however, the general excavation and support methods of the tunnels would not vary greatly based on the final use of the tunnel. Therefore, although the examples presented in Sections 12.1 and 12.2 are not exclusively highway tunnels, the case histories are valid to use as a reference for the feasibility of the SR-710 tunnel.