Looking Underground for Traffic Relief

Feasibility study examines tunnel possibility

By Paul Guptill, Sr.

Likely one of the most congested segments of highway in the nation, the 30-mile stretch of Southern California's Riverside Freeway (State Route 91) carries some 280,000 travelers every day. Already part of previous widening projects to accommodate growth, the highway now stretches to 12 lanes including four high occupancy toll (HOT) / high occupancy vehicle (HOV) lanes along portions of the route.

Yet, there's been little relief as this is a primary corridor between Riverside and Orange counties—and traffic is expected to get much worse. According to California transportation authorities, traffic is projected to grow so much between now and 2030 that the highway would have to expand to 22 lanes to handle the projected demand of 480,000 vehicles per day. The Orange County Transportation Authority (OCTA) and the Riverside County Transportation Commission (RCTC) are working together to develop strategies to alleviate the congestion.

Tight scheduling on the project required one crew to drill at night.

One possibility is to go underground.

As part of a joint powers agreement, OCTA and RCTC have contracted Kleinfelder (www.kleinfelder.com), an engineering consultant firm, to complete the Irvine-Corona Expressway (ICE) Tunnels Feasibility Study. The study is a focused, field-based geotechnical evaluation of the deepest four-mile long segment of the proposed 11.5-mile tunnel corridor, as well as the surrounding area. The purpose of the feasibility study is to evaluate the most extreme rock and groundwater conditions along the alignment for challenges to the feasibility of design and construction of such tunnels.

OCTA and RCTC are evaluating several design concepts for the ICE Tunnels, which would pass under the Santa Ana Mountains that separate the two counties. The paired tunnels would be about 50 ft in diameter, 11.5 miles long, and ultimately carry about 70,000 cars per day.

Naturally, one of the top concerns is the impact of construction and operation of the ICE Tunnels to the environment. A key condition in the possible construction and operation of the tunnels is to have little or no impact on the existing Cleveland National Forest's delicate and limited groundwater resources, wildlife, habitats, and the environment.

In fact, the United States Forest Service (USFS) states that these tunnels cannot affect the habitat of the Cleveland National Forest by draining away groundwater in the mountain. Draining away groundwater is typical practice in most tunnel construction around the world, but because springs and stream flow keep the ecosystem in balance and support wildlife and sensitive habitats in the Santa Ana Mountains, springs and groundwater must remain unaffected with this project.

Over the course of nearly 18 months, Kleinfelder worked with the USFS to reach an agreement to conduct necessary geotechnical studies. The key factors that the forest staff evaluated during that time included defining the nature of the work, the area of study, what habitat resources would be disturbed, and how the USFS would be compensated for the extra work that would be required for monitoring the field drilling activities. (A significant delay in the permitting process was the Santiago Fire that burned a large part of the Cleveland National Forest south of the study area in the fall of 2007, diverting USFS personnel to the tasks of fire fighting and recovery.)

To satisfy the USFS groundwater requirements, it was agreed to gather information on the groundwater system by:

1. Drilling holes and measuring groundwater pressures using vibrating-wire pressure transducers installed at the tunnel depth and shallower.
2. Monitoring water resources for a year by collecting data on regional springs, stream flows, water wells, and water chemistry.
3. Installing and monitoring rain

gauges during the year of water resources monitoring.

In the end, Kleinfelder and USFS defined five remote, protected sites accessed by helicopter to conduct the necessary rock coring and well installation studies. These sites were spaced out along the potential tunnel corridor over about four miles.

The current feasibility study was limited to within the Cleveland National Forest, simplifying the access permit requirements of the study. The USFS special use permit included an "Operations Plan" of field activities and "Fire Plan" outlining fire safety protocols. A full-time fire monitor was also required with each drill crew during all field operations.

Limited Access

In early April 2008, Kleinfelder engineering geologists began flying by helicopter into the Santa Ana Mountains to begin geotechnical studies that would help determine the forest's groundwater level and the type of soil and rock that would need to be mined to build a tunnel.

Almost daily, there were as many as four crews consisting of one engineering geologist, one fire monitor, and two or three drill crew members participating in the study.

The crews would report to Corona Airport, where they would embark on their daily flight to each work site followed by a return flight at the end of the shift. Because of the tight scheduling, one site included a night crew.

Each of the sites included a nearby landing pad cut out of the chaparral-covered ridges. On foggy days, the crews would drive into the forest and then hike one or two miles to the drill site from the nearest forest service road. Periodically, USFS personnel would visit the sites to check compliance with the Special Use Permit and Fire Plan.

Once at a site, engineering geologists conducted the test borings that will help document the existing rock mass conditions and range of seasonal changes in groundwater that occur due to rainfall and dry seasons. If tunnel construction activities are predicted to change the groundwater system and surface springs, then design engineers will have to develop tunnel construction methods and final tunnel design systems to prevent possible environmental effects. Such systems may include gaskets between tunnel lining segments, grouting ahead of the tunneling operations, and supplementing water resources artificially within the forest.

The drill site was so remote, crews had to be flown in by helicopter, followed by a drive into the forest, and then a one- or two-mile hike.

Beyond groundwater issues, engineers must avoid the Elsinore fault line—part of the San Andreas system that borders the east flank of the Santa Ana Mountains—and identify other fault lines, if any, that intersect the tunnels. Generally, earthquakes do not damage tunnels because the ground motions induced by an earthquake are not felt as strongly below ground as at the surface. Typically, below ground transportation roads, such as tunnels, are as safe as or safer than surface roadways.

The most severe damage potential from an earthquake on a tunnel could be where an active fault line intersects a tunnel. During an earthquake, the shift of the ground on either side of a fault that experiences offset can rip apart the tunnel lining and displace the alignment of the tunnel across the fault. This is difficult to repair and would cause severe damage if fault displacement may occur.

To avoid such a situation, the ICE Tunnels would be located west of the Elsinore fault line so as to not be affected by the faulting. With the ICE Tunnels placement, even if a ground shift were to occur at the Elsinore fault, the tunnels should remain unaffected.

From a design standpoint, a key concern is the potentially crushing hydrostatic pressures on a tunnel as deep below the ground surface as the ones proposed.

To evaluate the potential water pressures at the tunnel elevation, Kleinfelder installed pressure transducers to measure the pressure at the depth of the tunnel and shallower. The deepest corehole was drilled 1,502 ft below ground. The information gathered from the transducers will allow designers to better anticipate conditions at the tunnel depth and prepare design solutions that would resist the high water pressures.

Pressures vary with depth due to the greater height of water at greater depths. For the preliminary profile of the tunnel before any field investigations, the depth of the tunnel was placed no more than 750 ft below predicted groundwater to limit the amount of pressure on the final tunnel lining.

From Corona Airport, crews were flown by helicopter to the landing pad at the drill site.

Project engineers have found that the pressure gradient is not continuous along the proposed corridor because of variations in rock conditions or natural barriers that prevent water from connecting across those barriers.

Often the pressure at depth is less than the predicted hydrostatic pressure because of those barriers and separation of groundwater bodies. The lower water pressures can be beneficial for tunnel design by allowing the tunnel to be lowered in elevation, reducing the road gradient beneath the mountains. Also, the lower pressures against the tunnel lining may allow designers to use more efficient and lighter-weight lining systems to resist the lower water pressures.

Thus, for the ICE Tunnels, the worst case of highest groundwater pressures was assumed for the preliminary road profile, and the current studies are helping to refine the profile according to true groundwater conditions.

The field rock coring phase of the work was completed in early November. Now, the team must begin the complex task of compiling and evaluating the immense database of rock mass conditions and groundwater from the study. The evaluation phase of the work is expected to continue through the end of 2009, when the findings and conclusions will be presented to transportation authorities. GE

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