Protecting Utilities on the World's Largest Tunnel Project

BY DAVID SOWERS, P.E.

At 10:54 a.m. on February 28, 2001, the Puget Sound region in Washington state was rocked by a 6.8 magnitude earthquake. While it only lasted 45 seconds, the earthquake had a sudden and long-lasting effect on the public's view of the State Route 99 Alaskan Way Viaduct. Constructed in the 1950s when earthquakes were little understood and soil liquefaction even less so, the viaduct has tirelessly served the Seattle metropolitan area and the 100,000 vehicles using her daily for more than 60 years. The structure survived the earthquake, but within a few months, experts concluded what we suspected all along: it was time for a replacement. Yet this isn't just a simple bridge or a highway. The viaduct is a bit of both, surrounded by 60 years of development, historic neighborhoods, and one of the largest ports on the West Coast.

Fast forward to 2009. Informed by years of study and public input, including a yearlong stakeholder process, leaders from the state, city of Seattle, King County and the Port of Seattle recommended a single deep-bore tunnel, along with a host of other improvements, to replace the viaduct. The tunnel would allow crews to keep the viaduct open to traffic the majority of the time while its replacement was excavated out of public view.

By 2010, WSDOT's project team had assembled a preliminary design and contract documents for tender. WSDOT selected the "design-build" project delivery method as the best approach to constructing this technically challenging project. Seattle Tunnel Partners, a joint venture of Dragados USA and Tutor Perini, was awarded the $1.35 billion tunnel project in December. STP's winning bid included plans to build a 57½-foot diameter earth pressure balance (EPB) tunnel boring machine (TBM), setting a new record for tunnel diameter.

Protecting Infrastructure

Most, if not all, construction contracts include the provision that "existing structures be protected in-place." For tunnel projects in heavily urbanized settings, nothing could be more important and potentially more difficult to achieve. The very nature of underground construction requires close observation of the soil and groundwater conditions, and an understanding of the ground's potential response to tunneling. Soft ground tunneling requires removing soil and replacing it with a pre-cast concrete liner, which inherently can equate to some ground shifting and eventual settlement. With the earth pressure balance technology being employed on the SR 99 Tunnel Project, such ground deformation will likely be minimal. However, even slight amounts of ground movement could damage 100-year old waterlines and a railroad tunnel that moves 50 trains per day.

Downtown Seattle is home to multimillion-dollar properties and an underground network of utilities that serves them all. Some of the key utilities along the tunnel alignment include electrical transmission and distribution systems, traffic lights and signals, waterlines, steam, natural gas lines, and communication systems. Each of these facilities, whether public or private, have deformation criteria that the utility owners consider conservative markers before movement could damage the utility or disrupt service. WSDOT developed contract provisions to capture each of these criteria and explained the potential risks to ensure bidders fully realized the high standard for controlling tunnel-induced settlement.

The tunnel boring machine must also pass beneath the viaduct it's working to replace, and this must be achieved without causing any significant damage that could interrupt its operation, or worse, prematurely close it. Ensuring the project team can track movement of

so as not to be confused with real construction-causing damage. While not always perfect, these surveys also, if used correctly, can help smooth relations with difficult property owners (or public infrastructure owners). Showing a willingness to protect their assets and explaining the reasons why can reduce acrimonious relations that can only sour further when damage is then detected. On this project, WSDOT has had much success building relationships with private property owners along the tunnel route and obtaining the necessary property rights to instrument and monitor structures and utilities.

buildings, utilities, rail tunnels and other structures at the moment they may occur and make operational changes to the TBM are keys to the project's $20 million instrumentation and construction monitoring program.

Construction Monitoring

Monitoring tunnel construction focuses on two key areas: (1) Monitoring the TBM operation and (2) Monitoring the ground and structures above the TBM's path. First, Seattle Tunnel Partners, in partnership with Hitachi Zosen, the manufacturer of the machine, monitors numerous sensors and gauges to ensure the machine is not over-mining and causing unintended ground deformation. These sensors, many of them located in the cutterhead and in the TBM "skin", monitor earth pressures, excavated muck volumes, backfill grout quantities and pressures, to name a few. Real-time measurements allow the contractor to quickly make adjustments to the TBM's operations when alert levels are approached. If these alert levels are reached, the tunneling and monitoring teams meet to consider implementation of corrective measures to mitigate and arrest the deformation with tools internal or external to the TBM.

Depending on the data trend, the team may elect to increase the monitoring frequency and reassess the risk of the facility more closely. In one case, during excavation of the 80-foot-deep launch pit, crews chose to shut off a water line when the settlement caused by construction dewatering exceeded maximum allowable criteria of 1.6 inches. This was possible because there was a second service to the customer available. While this option is not always available, in an urban environment where multiple loops exist, it is certainly something the construction team can consider.

Methods for monitoring utilities were described in great length in contract specifications (or technical requirements), with one important reminder: Provide flexibility for the contractor, whether design-bid-build or design-build, so that alternative approaches and innovation is encouraged. Often designers (like the author!) sometimes forget that technologies are advancing well ahead of contract standards. Flexible specifications and open-mindedness can yield savings on any size project.

Secondly, monitoring best arms the owner for third-party claims. Judicious pre-condition surveys and real-time monitoring go a long ways toward heading off claims, especially frivolous ones. This data will help explain trends, fluctuations in seasonal weather or building movement,

Utility Monitoring Tools

Closed Circuit Television (CCTV) Inspection – A common risk management tool for sanitary sewer and drainage lines is to establish pre-condition surveys using CCTV inspection. Specially designed cameras are pulled through sanitary and storm sewers from manhole to manhole to document and establish conditions ahead of construction. As part of WSDOT's contract provisions for this project, these surveys were required along every linear foot of sewer larger than 6 inches in diameter within the tunnel construction monitoring zone. This established a condition to then be compared to post-condition video to assess if tunneling (or any other related construction) caused damage. The owner and contractor can then decide upon agreeable repair approaches to the utility based on the extent of damage. Without the pre-condition CCTV, this would not be possible and claims would be the only solution for the parties.

Leak Detection – For waterlines, the contract technical requirements required use of an acoustic leak detection system. Like CCTV's, pre-construction leak detection can establish a pre-tunneling condition, as well as locate susceptible water lines that should be repaired or replaced ahead of construction. With many of the waterlines over 50 years old, particularly in the historic neighborhoods, this level of pre-assessment helped to manage the risk of waterline settlement.

Utility Settlement Points – More low tech than video, another well-used monitoring approach is to set up manual survey points on the various utilities. This project used manual monitoring points on water valves, sewer manholes, and electrical vaults. Between utility surface features, Seattle Tunnel Partners also used Utility Settlement Points (USP), where utilities are relatively shallow (less than 10 feet deep). The USP's consists of a steel rod set in epoxy attached to the crown of the utility. A surface monument cover protects the steel rod from vehicles and construction equipment. Baseline readings are established for the USP and then is read weekly, and then daily, as the TBM passes beneath the utility of interest. For electrical vaults, where access was permitted, manual surveys were supplemented with pre-condition photos and videos. Due to the high voltage, these pre-condition surveys were performed for the contractor by the electrical utility itself.

Conclusion

Monitoring public and private infrastructure is an essential part of building the world's largest bored tunnel. The SR-99 Bored Tunnel's extensive instrumentation program is key to minimizing utility damage and (worst case) determining the extent of damage. The instrumentation approaches described herein, both simple and high tech, have the ability to protect the project owner, the utility, the contractor, and the public from possible ground movement before real damage occurs.

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