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FEATURE STORY

Roadheaders in North America

A Look at Machine Selection and Case Studies

By Karl H. Mitterndorfer

The role of roadheaders in North America as a means of tunnel excavation has increased substantially over the last decade. But it still falls short of the widespread utilization throughout Europe, where engineers have a more favorable view of roadheaders for specially designed tunnels with a length of 3 km or less, especially for projects in metropolitan or populated areas.

The fact that Europe is more densely populated than North America (with exception of metropolitan areas) makes mechanical methods of excavation more popular. It limits the noise and safety concerns affiliated with drill and blast. However, as North America's population continues to grow and the security concerns stemming from the Sept. 11 attacks are an everyday reality, roadheaders and other mechanical methods are likely to become more commonly used.

This leads to the evaluation of which mechanical method of excavation — the TBM or the roadheader — is more suited for a tunnel and, if the roadheader is the most efficient method, what model should be selected. The TBM is the most popular and cost-effective method of mechanical excavation worldwide. For longer tunnels it can achieve unparalleled production rates in various types of material while providing the foundation to put an extensive tunnel support system into place.

Heading Toward Acceptance

In North America, TBMs are often the first choice, but there are types of tunnels for which TBMs are not suited. In short tunnels, tunnels with geometrical abnormalities and in tunnels with sharp radius turns, TBMs are not the desirable option as they do not offer the flexibility and maneuverability that is necessary. For the forementioned tunnels, given favorable ground conditions, the roadheader is the obvious option for European engineers and should more commonly be considered in North America.

Today's roadheaders offer contractors the flexibility that the TBM lacks and the capability of economically cutting rock with a hardness of up to UCS 25,000 psi. The potential liability issues involved with the drill and blast method in populated areas can be avoided through the use of mechanical excavation, which does not create significant or dangerous noise and vibrations.

Part of the skepticism in North America stems back to the introduction of roadheaders in the 1970s and 1980s. Throughout this period and extending into the 1990s, unrealistic expectations and promises were made — leading to mixed results and some criticism during the initial 20 years the machines were used in the United States and Canada. Coupled with questionable machine reliability and poor service during these early years, contractors who recall those days were fairly reluctant to use roadheaders and often shied away from them — even though they could have been the most cost-effective solution for their job. This ambivalence has diminished some over the years through some higher quality roadheaders that are available in North America through suppliers that offer accurate consulting, a readily available spare parts supply and professional after sales service.

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Geotechnical Considerations for Roadheader Selection

With ongoing development of mechanized excavation methods (roadheaders, TBMs etc.) and the development of stronger cutting tools, roadheaders are able to economically cut harder material than ever before. Nevertheless, rigorous geotechnical tests need to be conducted and analyzed prior to selecting the correct roadheader for the given application.

The most critical pre-investigation is core-drilling and the examination of the cores. The analysis of the cores should include:

- Detailed description of rock layers, including rock type, degree of weathering and prevalence of fractures
- Quantification of cleavage systems (degree of core recovery, RQD-Index average single core length)
- Description of cleavage plains (open or closed, flatlocked, bestained)
- Petrographical analysis of the important rock types covering mineral content, texture, grain size
- Evaluation of compressive strength and tensile strength (Brazilian Method), cohesion and angle of internal friction for soil
- Abrasivity measured by the CERCHAR Abrasion Index (CAI)

Based on the results of the testing and the dimensions of the tunnel, a decision as to what size roadheader should be used can be made. But the size of the roadheader is not the end of the decision-making process. Technology and innovation has made more options available to increase overall efficiency and safety — not only for excavation, but also the installation of support systems in New Austrian Tunneling Method (NATM) tunnels. Some of these include:

- Arch erector to install lattice girders or steel ribs (mechanical or hydraulic)
- Working platform on top of the roadheader
- Drill boom to install rock bolts and/or arch canopy pipes (barrel vault method)
- Swivel belt conveyor
- Pick flushing system for dust control
- Guidance or remote control
- Diesel powered track drive for faster mobility

To achieve the optimal rate of production from a roadheader, the most critical step is the selection of the proper machine with the necessary options for the job at hand. It is essential that the contractor works together with the supplier throughout this process to ensure the most cost-effective solution is selected.

As roadheaders continue to become more favorable in North America, there are various recent projects that are evidence of this movement. A few of these projects are referenced below:

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Case 1: “El Tunel” Water Tunnel

In summer 2000, the Cerro Grande fire in Los Alamos, N.M., destroyed hundreds of homes and burned down some 45,000 acres of forest. A significant consequence of these fires was that the destruction of such vast vegetation made the area roads extremely vulnerable to flooding, as would be experienced in July 2001.

Torrential downpours overwhelmed the existing 84-in. diameter drainage system protecting the roads. More than 45 ft of water backed up on parts of area roadways, making it clear that a water tunnel was needed.

In 2003, Twin Mountain Construction II Co. (TMCC) was awarded the project and selected a rebuilt AM50-M roadheader for the bulk of the excavation of the 14-ft diameter (excavated), 613-ft long tunnel. This selection was based on the short length of the tunnel, the material and the general instability that existed within the ground conditions of the area — which made drill and blast a less desirable alternative.

Conditions were relatively soft sandstone with average UCS up to 6,000 psi. The tunnel support included Antraquip’s lattice girders, wire mesh and shotcrete. Given that the structure was on a curve, keeping the tunnel online was one of the most challenging aspects of the project.

Despite the challenges, an advance rate of 24 lf per day was achieved and the project was completed a month ahead of schedule. This was especially important given the time sensitivity of the project, which was due to the start of the rainy season in July.

Case 2: Metro Line 2 Tunnel

Another project displaying the successful use of a roadheader in North America was the Metro Line 2 extension to Laval in Montreal, Quebec, Canada. This project required a 5.2-km tunnel starting in Laval and connecting to the Henri-Bourassa Station in Montreal. Construction of this tunnel, which is designed to reduce rush hour traffic in the outskirts of Montreal, commenced in July 2002.

The common method of excavation for this region in the past has been drill and blast. However, for this project there were two major concerns. First, parts of the tunnel were to be built in a densely populated area and some segments were designed to be only 10 to 27 m below the surface —

bringing liability concerns into play. These stemmed from vibration and noise associated with drilling and blasting. Complaints, litigation and the possibility of substantial delays were all factored into the decision to use a roadheader to excavate a substantial portion of the tunnel.

The other consideration related to geological conditions encountered throughout the project. By drilling and blasting in this material, which consisted of predominantly limestone with seams of shale, significant overbreak was anticipated. This would cause delays as excess material would need to be removed and more concrete would be needed to compensate for this overbreak.

These considerations along with rigorous testing of the material resulted in the selection of a 120-ton Voest Alpine ATM105-IC roadheader. This roadheader was able to economically cut the material, the majority of which consisted of limestone with an unconfined compressive strength of up to 134 MPa (approx. 19,500 psi).

The electrically powered ATM105-IC came equipped with a water spray system for dust suppression and has a maximum cutting profile of 50 sq m. Although the production rate for the roadheader far less than drill-and-blast methods, it achieved a satisfactory production rate given the range of production expected from roadheaders. The productivity averaged 9.8 m per double shift in the tunnel with 5.6 m radius in material with an average UCS of 90 to 100 MPa.

Drill-and-blast methods were used to simultaneously excavate the second of three segments, but based on numerous complaints of property damage from blasting, the contractor opted to purchase another roadheader to complete the final segment.

Case Study: Dulles Airport West Utility Tunnel

The West Utility Tunnel was the first of several tunnels to be constructed for the Metropolitan Washington Airport Authority as part of an expansion program. The purpose of the West Utility Tunnel is to enable large-bore heated and chilled water to be brought in from the utility building to terminals A and B at Dulles Airport.

The WUT was designed to be 1,030 ft long with a height at the crown of 17 ft and a width of 21 ft. The material to be excavated was a mix of claystone, siltstone, mudstone and sandstone with a UCS ranging from 4,000 to 15,000 psi. Given tunnel specs and geological makeup, the decision to use a roadheader was apparent to the designers ILF Consultants, and the contractor, Kiewit Construction. The use of drill and blast was also not an option, due to security and safety concerns and the proximity of airport activities.

Also, considering the relatively short length of the tunnel and high mobilization costs, a TBM would not have been an economic solution. After considering the various roadheaders which are available, Kiewit selected two roadheaders, one rebuilt and modified Voest Alpine AM75-M and an AM50-M both supplied by Antraquip Corp. The electrically driven AM75-M has an operating weight of 114,600 lbs, a max cutting height of 16 ft, 2 in., maximum cutting width of 24 ft, 11 in. and the ability to undercut 6 in.

The project was an overwhelming success as an advance rate of 8 to 10 ft was achieved per day, enabling the excavation of the tunnel to be completed by January 2005 — well ahead of expectations.

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