Abstract

Switzerland’s Ceneri Base Tunnel will cut rail travel times between Lugano and Bellinzona in half once operational. Between February and November 2008, a 9.7 m diameter Robbins Main Beam TBM initiated the first phase of construction. The machine bored the 2.4 km long main adit tunnel in Sigirino under high cover of approximately 600 m and in hard rock up to 130 MPa UCS (Unconfined Compressive Strength). The project was successful due to larger diameter 19-inch (483 mm) disc cutters, which are larger than the industry standard 17-inch (432 mm) size. The 19-inch cutters provide greater wear volume and are capable of excavating harder rock. This paper will examine the Ceneri Base Tunnel Project and superior performance of the 19-inch cutters compared to similar TBM projects utilizing 17-inch cutters.

19-inch Disc Cutters Dig Ceneri Base Tunnel

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Located in Switzerland’s Canton Ticino region, the Ceneri Base Tunnel Project will involve construction of twin 15.4 km long main rail tunnels running in North and South directions between Camorino and Vezia. The first stage of construction, prior to excavation of the twin tunnels, involves boring a main adit at the halfway point along the rail route, in the town of Sigirino. A contract was signed in April 2007 for the 2.4 km long adit tunnel with the Consorzio...
Monte Ceneri (CMC) JV—a consortium of CSC, Lugano, Frutiger SA, Thun, Rothpletz, Lienhard + Cie, and Aarau. The Robbins Company was contracted to supply a 9.7 m diameter Main Beam TBM, which had previously bored successfully on the main headrace tunnel of the Kárahnjúkar Hydropower Project in Iceland.

Contracts for the Ceneri main tunnels were put out to tender in March 2008. The contract will include two 8 km sections of D & B (Drill & Blast) tunnels for the north running main line, and for the south running line will include two 1.8 km sections of D & B and two 4 km sections of either TBM or D & B tunnels (with selection left up to the contractor). Excavation of the main lines is scheduled to begin in early 2010.

1 - ADIT TUNNEL CONSTRUCTION

The proximity of the adit tunnel to the town of Sigirino led the contractor to opt for a TBM-driven heading, as D & B was likely to disturb nearby residences. The jobsite space itself was limited, making muck storage nearly impossible.

To cope with the restricted work area, the project was designed to utilize an internal concrete batching plant constructed from a drill-and-blasted cavern that could be operated 24 hours a day. Muck was transported via an overland conveyor system to a temporary storage area about 1 km from the jobsite. The muck, consisting of high quality gneiss, was recycled as aggregate for concrete in the batching plant.

The adit will be used as a starting point for excavation of the main tunnels. An initial exploratory bore was used to determine the geology, consisting of schist, Swiss molasse, and Ceneri orthogneiss with a UCS of 30 to 130 MPa. The Robbins machine was checked and modified to suit the rock types present.

Machine components were shipped to the Sigirino jobsite in early 2008 after refurbishment and diameter change of the TBM from 7.6 m to 9.7 m in a facility near Milan, Italy. The machine was launched on February 15, 2008 in ground consisting of biotitic gneiss around 130 MPa UCS.

The TBM was designed as a High Performance (HP) Main Beam machine, utilizing larger diameter cutters. The cutterhead design was the first of the TBMs on the Alp-Transit tunnels to use back-loading 19-inch disc cutters, a design that offers both longer cutter life, reduced cutter change downtime and higher penetration rates compared to the standard 17-inch size.

A large, open working area behind the cutterhead also allowed crews to install a variety of ground support depending on the conditions encountered. Ground support included installation of wire mesh on the top 240 degrees of the tunnel diameter, as well as three rock bolts and 1.4 m³ of shotcrete per meter bored. Crews also installed continuous drainage pipe and filled the invert with 1.6 m thick concrete behind the TBM to prepare the tunnel for track installation.

The Robbins Main Beam TBM successfully excavated hard rock up to 130 MPa UCS

2 - TBM PERFORMANCE WITH 19-INCH DISC CUTTERS

The Robbins machine successfully completed the adit tunnel within its project schedule on November 6, 2008. Correct cutterhead design resulting in lower cutter usage and high advance rates were arguably contributing factors in the machine’s success. « Cutter performance has been the single most impressive result of this project », said Ferruccio Borrioni, General Manager for Robbins Europa.

The disc cutters excavated a combined total of 167,000 cubic meters of hard rock during the bore, and the machine recorded average advance rates of 18.5 m per day. Cutter wear was minimal throughout the bore, requiring less downtime for cutter changes. « We changed only 30 cutters in the last kilometer of boring. This is a very good result », said Emanuele Tabet, Jobsite Director for the CMC consortium.

Greater cutter life and penetration are the factors that result in higher advance rates for TBMs employing 19-inch disc cutters. 19-inch disc cutters can be operated at 311 kN load compared to the 267 kN load limit of a 17-inch cutter. Even at the higher operating load, roller bearing life is higher in 19-inch cutters. When operated at 311 kN, the 19-inch cutter bearing is only at 84% of its roller bearing load rating whereas the 17-in cutter when operated at 267 kN is at 93% of its roller bearing load rating. The higher capacity roller bearing, together with improved lubrication, results in fewer bearing failures and better penetration in harder rock.

The increase in cutter ring diameter results in increased cutter life. Allowable ring wear volume, the amount of ring material that can be worn before a cutter must be changed, is increased by over one-third in 19-inch cutters. The increased wear volume means more cubic meters of rock can be excavated per cutter ring, resulting in fewer cutter changes. Fewer cutter changes results in less TBMs downtime and ultimately faster tunnel production rates overall.
More recently, Robbins has developed even larger 20-inch rings. By increasing the cutter diameter further the 20-inch wear volume is 58% greater than that of 19-inch cutters, providing even more pronounced effects on cutter life and cutter changes. 20-inch rings are currently being used on two 10 m diameter Double Shield machine boring the AMR project in India—the world’s longest tunnel without intermediate access at 43.5 km. The 20-inch rings are also mounted on the world’s largest hard rock TBM, at 14.4 m in diameter, currently boring a 10.4 km tunnel under Niagara Falls in Canada.

3 - COMPARISON WITH PROJECTS UTILIZING 17-INCH CUTTERS

There are many examples from recent projects to support improved advance rates with 19-inch cutters. One example is the Hallandsås Project in Sweden—a rail project consisting of twin 8.6 km long, parallel tunnels connecting Gothenburg and Lund, Sweden. A 10.53 m diameter Herrenknecht Mixshield was selected to bore through heavily fractured gneiss, amphibolites, and dolomite exceeding 250 MPa UCS with significant water ingress. After damage to the cutterhead due to blocky ground and high abrasive wear to the cutterhead and cutting tools, it was decided to design a second cutterhead. Much of the significant damage to the cutterhead was concentrated in the mid-face area, where cutters tend to receive the highest loads. The cutter geometry was changed on the second cutterhead, and cutter diameter increased from 17 inches to 19 inches. Designers increased the cutter diameter to allow for higher loads (320 kN, compared to 250 kN for 17-inch cutters) and better cutter wear in the blocky ground (Dudouit & Sturk, 2008). After cutterhead replacement and changing of the 17-inch cutters for 19-inch cutters in spring 2008, progress rates have improved markedly, though the project completion date has been delayed significantly—nearly three years later than originally planned (T&TI, Nov. 2008).

A project still larger in scale is AlpTransit’s project in Switzerland, consisting of more than 150 km of rail through the Alps. Excavation of the Gotthard Base Tunnels began in 2002 and involves several Herrenknecht gripper TBMs with 17-inch cutters boring the parallel tunnels in eight different sections. Much of the tunnel is under a very high overburden, ranging from 1,000 to over 2,000 m in hard rock similar to that found at Monte Ceneri. Advance rates for the completed tunnels were about 11.5 m per day for both the Bodio and Amsteg sections, respectively (Erhbar, 2008). The Ceneri average of 18.5 m per day, using 19-inch cutters, was therefore 61% higher than both the Bodio and Amsteg averages achieved with 17-inch cutters.

CURRENT SITE CONSTRUCTION AT CENERI

A total of seven caverns with different cross sections are currently being excavated at the Sigirino site using D & B. The caverns, ranging from 105 m² to 264 m² cross-sectional area, will serve as construction logistics caverns, while the largest will become the internal concrete batching plant. As of February 2009, crews were installing invert segments in the main adit and excavating the main operations cavern. Construction work is ongoing at each of the portals for the parallel main tunnels in Camorino and Vezia. Crews have begun excavating the portal site for the open cut, 170 m long starter tunnel in Vezia near the south portal. Work near the north portal in Camorino is in the preparatory stages and will consist of undercutting a motorway in soft ground, as well as construction of several large caverns. Excavation of the main tunnels, beginning in 2010, will result in parallel single-track tunnels approximately 40 m apart and connected every 352 m by cross passages. Much of the construction will consist of drill and blast, as well as a 2.7 km long open section requiring two viaducts and a bridge to bypass several major roadways. All tunnels are scheduled to be operational by 2019.

REFERENCES

