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Toronto Metro - Sheppard Line Twin Tunnels

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Abstract: The City of Toronto operates a rapid transit system totaling 70 km in length. The system is used for local transport within the greater metropolitan area to transport large numbers of people (1,105,700-weekdays), often over short distances at high frequency. The Transit Commission's Sheppard Subway twin tunnels run east from the existing station on the Yonge line along Sheppard Avenue east to Don Mills Road. The tunnels were excavated using a Lovat-type earth pressure balance machine (EPB). This was the first use of earth pressure balance tunnel boring machines in the Toronto area.

Keywords: TBM; tunnel; tunnel lining; machine

1. Introduction

Due to the lower cost and its reduced impact on the community, the design mandated that the tunnel boring machine (TBM) be used to construct the tunnels. The cut and cover method was used locally, where the alignment was off the populated area and where the tunnel horizon was close to the surface. The excavated tunnel diameter was 5.9-m, while the internal diameter was 5.2-m. Tunnel alignment and project layout are shown in Figure 1

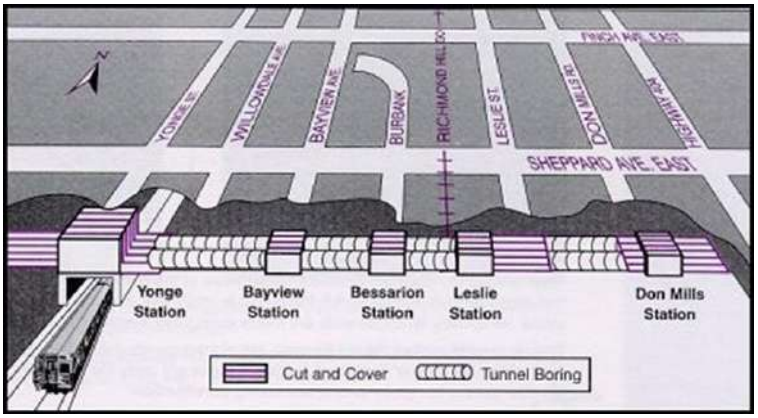

Fig. 1. Tunnel Alignment and Project layout

2. Tunnelling Conditions

Tunnels were driven through soil formations. In the greater Toronto area, the overburden deposits are generally clay/silt till. They are expected to exhibit numerous boulders. Most of the alignment was below the groundwater table.

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3. Contractual Arrangement

Tunneling work was done by a Canadian consortium of three local area contractors. The owner, Toronto Transit Commission (TTC), provided the machine and precast segmental lining. The TTC had procured the machines from Lovat, a manufacturer located in Toronto. Hatch Mott MacDonald was the prime consultant responsible for the detailed design and design support during construction.

4. TBM System

The key to tunneling in soil is to minimize surface settlement by maintaining the natural earth pressure at the tunnel face. As noted, Earth-pressure Balance (EPB) boring machine was used at the project. The machine was designed to allow the operator to switch from open mode in self-supporting ground to pressurized mode when positive support of the excavated face was needed. The development of earth pressure balance tunnel boring machine had solved the problem of having to pressurize tunnel face during excavation to prevent their collapse and the ingress of water.

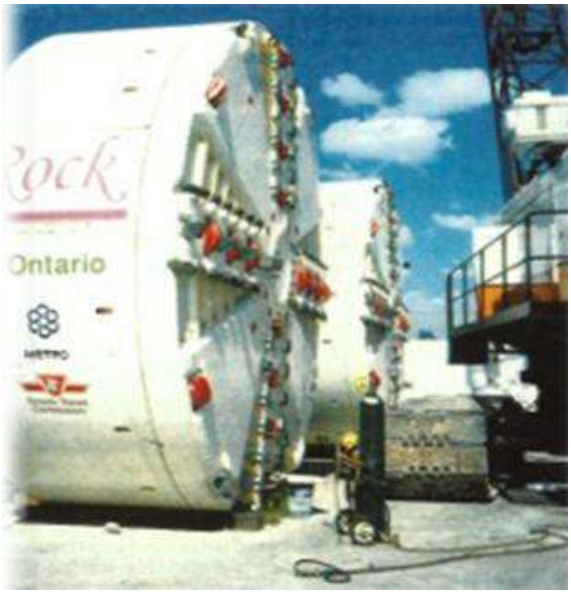


Fig. 2. View of Lovat TBM used for the project.

5. TBM Operational Aspects

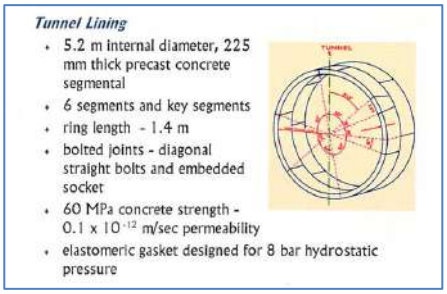
The system operated with good measurement and control of the excavated materials at all times. The actual volume of excavated materials was continuously compared with the theoretical excavated volume, and any deviation would alert the operator to potential ground loss problems.

Initially, it was estimated that the machine might be required to operate in a pressurized mode for about 80 percent of the total tunnel length. The balance of the tunnel (approximately 20 percent) was assumed to be excavated with the TBM in open-face mode when the tunnel alignment was located in a denser soil formation.

When significantly more boulders were encountered in the ground (more than forecasted), Hatch Mott MacDonald recommended replacing the machine's cutting heads with new heads designed for both cutting rock and excavating in soft ground. They also recommended adding protection devices to prevent large boulders entering the machine.

Fig. 3. View of tunnel portal

6. Tunnel Lining



The designers had to develop a tunnel lining that addressed the range of ground loading conditions. In addition, the lining had to be suitable for easy installation, the same time being economical. The system selected was a precast concrete lining made up of segmented rings that are bolted from ring to ring. The connections between the rings were designed to yield at a certain load level, allowing the rings to act as more flexible, independent units. The linings are made of high-performance 60 MPa concrete with very low permeability and diffusivity. The lining segments were equipped with standard EPDM gaskets designed for 8 bar of hydrostatic pressure, and were bolted radially and longitudinally with straight diagonal bolts. All the rings were tapered to provide tunnel direction control.

7. Conclusions

Tunnels were completed on the initially estimated 35-month schedule. The construction contract was well within budget and included less than 3% for contract changes. Critical elements of the project included dealing with difficult launch sites for the boring machine and operating the TBM in proximity to the existing storm sewer and water mains.

Acknowledgement

Award-winning firm was Hatch Mott MacDonald, Toronto (prime consultant). Hatch's design leaders were Brian Garrod, P.Eng. and Tomas Gregor, P.Eng.

8. Author

Mike Zegarec recently retired as a HATCH employee. His 46 years of experience have been in major heavy construction projects in North & South America, Europe and Africa. In 2023 Mike received an award from Tunnelling Association of Canada, titled: Canadian Tunneller of the Year. This award is awarded for leadership and the profound impact the recipient has had in the tunneling industry.