Technical Session C

A PERSPECTIVE ON CANADIAN TUNNELLING

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ABSTRACT

Around the world, most countries depend on hidden, yet vital, tunnels to provide life-sustaining fundamentals such as power generation, transportation, water supply and sewage disposal systems. The same is true here in Canada where the majority of the country's tunnels provide the municipal infrastructure required to sustain modern life in every city and town between the Pacific and Atlantic Oceans. Numerous hydroelectric facilities, including tunnels, were built in remote Arctic regions of Canada, some of which are beyond public (tourist) reach.

The paper provides a brief overview of Canadian tunnelling history, as well as current and future trends in tunnelling industry.

KEYWORDS

Tunnels, railway, transportation, hydro tunnels, mining, municipal, hard rock,TBM.

INTRODUCTION

The first tunnel in Canada was constructed in 1860 near Brockville, Ontario to provide rail access to the river. This half-kilometre tunnel is now a tourist attraction. In 1868 the Shanly brothers were called in to complete the Hoosac Tunnel bringing Canadian expertise to complete a tunnel in six years that had made little progress in the previous 16 years. Their contract was $5 million, a princely sum one and a half centuries ago. From the late eighteenth up to the mid-twentieth century, all major tunnels in Canada were associated with railways including many on the trans-Canada rail lines through the Rockies. Canada through this work and a burgeoning mining industry was at the forefront of tunnelling techniques. Further demands of our economic growth in the early twentieth century required larger size, road and rail tunnels to act as connecting conduits to the United States. Two famous tunnels, namely the St. Clair railway tunnel between Sarnia and Port Huron and a twin-tube sunken tunnel between Detroit and Windsor were placed in service in 1891 and 1910 respectively. For the St Clair Tunnel, Joseph Hobson introduced the use of a soft ground shield a cast iron segmental lining, a first for North America. The Detroit River Rail Tunnel represented the first known immersed tube tunnel in the world.

Canada has also been a leader in the development of mechanised tunnelling. Robbins experimented with their first TBM equipped only with cutting discs in Toronto in the early 1950's and Lovat from its beginnings in the late 1960's is now a world leader in the manufacture of tunnel boring machines.

CANADA: A YOUNG NATION WITH BOLD ACCOMPLISHMENTS

Municipal developments

As illustrated in Figure 1, the greatest number of tunnels constructed in Canada can be credited to the development of municipal infrastructure. Because of their normally small size, it is likely that no complete listing of these tunnels will ever exist. Prime reason for the general misconception as to the role of tunnels in Canadian every day life is the "out of sight, out of mind" character all too many important tunnels. Recently, an effort was made by the Tunnelling Association of Canada to identify and catalogue as many Canadian tunnels as possible. A comprehensive database can be found on the website titled "tunnelcanada.ca". Further growth of municipal tunnelling in Canada is well on its way and most recent estimates indicate that several thousand kilometres of water supply and sewage tunnels have been constructed beneath the Canadian cities.

Mine Tunnels

Similarly, mine tunnels are often abandoned and forgotten when a mining operation is complete, although the number and size of these tunnels outrank those required for civil works by a factor of ten. The Canadian mining industry is known throughout the world in hard rock exploration and tunnelling and many of these mining methods have been passed on to civil engineering projects throughout the years. The underwater tunnel off the cost of Cape Breton (Jack McKinnon), for example, was constructed by use of fully shielded Lovat TBM and was driven as part of coal mining development. The NORAD complex in North Bay is located in one of the largest mined-out spaces in North America, an underground facility of special usage that includes access tunnels of significant size.

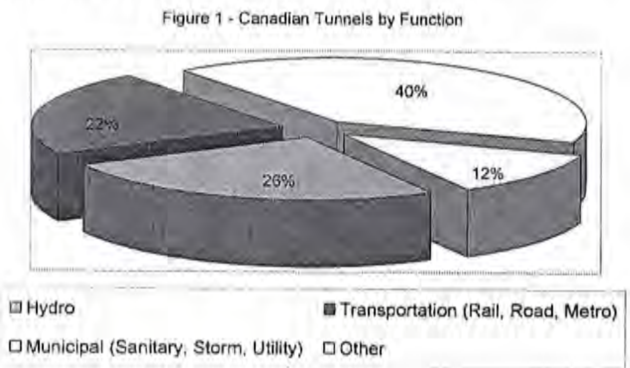

Figure 1 Canadian Tunnels by Functions

Transportation Tunnels

These generally fall into two categories – road and rail. Transportation tunnels are of paramount importance for a vast country, such as Canada. Development of Canada's transportation system and industrial base has been, and still remains, a challenge. In fact, some of our prominent recent developments were only made possible though the use of tunnels.

Urban rail or rapid transit tunnels are relatively new in Canada. Construction of the first subway began in Toronto, in 1949, using the traditional cut and cover method. Extensive tunnelling activities in the Toronto area followed, using mechanized techniques, with cast-in-place concrete and segmented linings. These tunnels advanced the application of shield methods used with compressed air and saw one of the earliest applications of a soft ground tunnel boring machine. Most recently, a 4.0km Sheppard subway line was constructed using two pressurized face, 6-m diameter Earth Pressure Balance (EPB) Lovat machines to excavate through glacial soil formations and demonstrated the huge improvement in advance rates and safety in tunnelling that has been achieved in the intervening years. EPB was selected as the best method to advance the tunnel through varying ground conditions in a densely populated urban environment. This is the second time that the EPB system has been used on large tunnels in Canada. The technology was first used to bore a 8.4 -m internal diameter tunnel under the St. Clair River in Sarnia – the largest EPB soft ground tunnel in North America. This tunnel paralleled the earlier tunnel by Hobson referred to in the introduction. The Sequential Excavation Method (SEM), a modification of NATM, developed for the Edmonton, Alberta rapid-transit system in the mid-eighties, was used to control running sands ahead of the tunnel face. Two other early rapid-transit lines, one in Vancouver and the other in Montreal, were constructed in rock using conventional drill-and-blast excavation, with cast-in-place concrete linings. Latest developments in subway construction in Montreal have made extensive use of roadheaders to excavate limestone, again demonstrating Canada's leading edge in the application of new techniques. In Vancouver, a new transit line is planned to the airport that will extensively use tunnelling.

Road tunnels are generally short and primarily located in the mountain regions of British Columbia on Canada's west coast or under watercourses in eastern Canada. Some of Canada's road major arteries are connected via sunken-tube tunnels, which were constructed on the bottom of major river crossings. One is the famous Detroit-Windsor automobile tunnel, built in 1930s and still in service today. Two other major tunnels include Montreal's Louis-Hippolyte- Lafontaine Tunnel (L-H-F) under the St. Lawrence River (just downstream from the 1967 World's Fair (Expo '67) site and the George Massey Tunnel, constructed in the 1960's, under British Columbia's Fraser River just south of Vancouver.

Figure 2 St. Clair Tunnel - EPB Lovat System with Segmented Lining.

Water tunnels

Water tunnels are primarily intended for hydropower generation. Large diameter tunnels are required for river diversion and to supply water to the powerhouse. In Canada, hydropower is utilized extensively for everyday energy consumption needs, while a portion of the power is exported to the U.S. The major hydropower developments in Canada occurred mid-century. Tunnels in this category are often required to operate under high internal pressures, and may be either concrete lined or unlined, depending on rock conditions. For this reason, almost all tunnels for power projects are in rock. Dozens of projects of this nature were constructed in the mountainous regions of Quebec, Newfoundland and Labrador and British Columbia. One huge project, the Sir Adam Beck Development built on the Niagara River in the mid-1950's, uses 14-m diameter tunnels excavated through highly stressed sedimentary rock. Since the 1960s in British Columbia, impressive projects such as the Peace River / Portage Mountain Development, the later Mica and Revelstoke Developments on the Columbia River and others required major tunneling works for water diversion and power facilities. The La Grande complex owned by Hydro Quebec and the Churchill Falls Development owned by Newfoundland and Labrador Hydro are world-scale projects where rock tunnels and underground powerhouses are the norm.

Figure 3 La Grande Underground Powerhouse, LG-2, Hydro Quebec.

SPECIAL PURPOSE CANADIAN TUNNELS

Special purpose facilities have been constructed in Canada in the last three decades. These include a military NORAD facility near North Bay, Ontario; AECL's Underground Research Laboratory (URL) to evaluate the concept of disposing high-level nuclear waste and the high-tech Neutrino Observatory at Inco's Creighton Mine in Sudbury, Ontario.

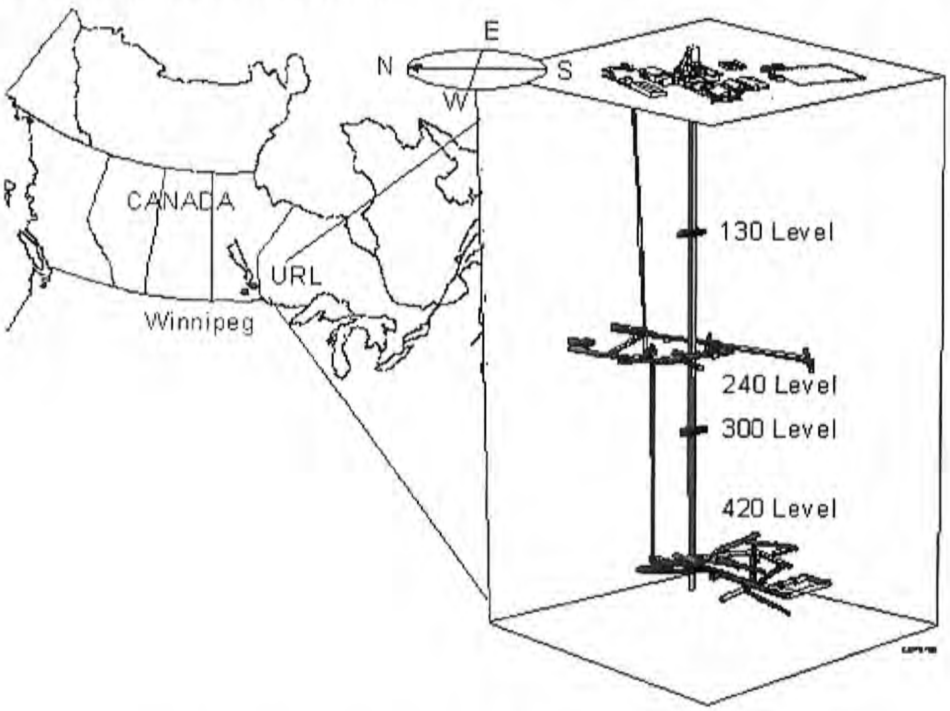

Figure 4 Underground Research Laboratory, AECL, Pinawa, Manitoba

FUTURE TRENDS AND CHALLENGES

The immediate focus will be on transportation links between new suburban areas and larger urban centers. Cleaning our beaches and revitalizing our waterfronts will be other priorities. A revitalized waterfront in Toronto, for example, would include over 400 acres of new parks and open space, a continuous waterfront promenade, new cultural and tourism facilities, 40,000 new housing units and 10 million square feet of new commercial space to feed new economy businesses. The proposal had called for the replacement of a section of the elevated Gardiner Expressway with a tunnel structure but this has been recently voted down because of the cost of this undertaking. Such programs will require additional water treatment facilities and new combined storm-sewage tunnels as well.

In the hydropower sector, new sites are being studied. Newfoundland & Labrador Hydro propose the development of a new generating station at Lower Churchill River (Gull Island), Labrador in association with the Province of Quebec. With an estimated capital investment of approximately $4 billion and a capacity of approximately 2,000 Megawatts (MW), this renewable energy development has the potential to contribute significantly to the provincial and national economy during both the construction period (2004-2010) and production stage, anticipated to commence in 2010.

Figure 5 Churchill Falls 6500MW Underground Powerhouse

Hydro-Quebec plans to develop the Eastmain River power site EM-1. The EM-1 powerhouse will be a surface powerhouse with underground penstocks and will have an installed capacity of 550 MW. Hydro-Quebec has also begun construction of the 526 MW powerhouse on the Toulnustouc River. Excavation for the powerhouse is underway and work on the 11-m by 13-m by 8.5-km long power tunnel will begin this spring.

Ontario Power Generation is in process of launching a tunnel diversion project at Sr. Adam Beck Generating Station in Niagara Falls, Ontario. At ten kilometres long and 12.5 metres diameter tunnel would require the world largest rock TBM and would represent an opportunity for further development of Canadian technical proficiency.

Engineering studies for an additional 100 MW electric power at BC Hydro's Brilliant site are underway in central British Columbia.

In the transportation sector, new extensions to the existing subway, Light Rail Transit lines and commuter rail systems are planned for Toronto, Ottawa, Montreal, Vancouver, Calgary and Edmonton. Many of these extensions will involve significant tunnel works. A new US/Canada cross border tunnel is presently in the planning stage as well.

In water and wastewater, a new outfall tunnel is planned for the Toronto treatment facility. Toronto and various other cities in Canada have ongoing sewer system expansions driven by residential development. Additionally, several cities have ongoing CSO abatement programs involving tunnelled storage.

TUNNELLING ASSOCIATION OF CANADA

The Tunneling Association of Canada (TAC) provides a central voice and perspective for all persons interested in tunneling. This national body represents Canada at all international forums, including the International Tunneling Association (ITA). One of its mandates is to maintain and publish a Canadian Register of tunnels, underground excavations and similar works. In this regard, the Association has compiled a catalogue of Canadian tunnels, which can be accessed at www.tunnelcanada.ca

CONCLUSION

The greatest number of tunnels constructed in Canada can be credited to the development of municipal infrastructure. Further growth of tunnelling in this sector is well on its way and most recent estimates indicate that well over several thousand kilometres of water and sewage tunnels will be constructed beneath the Canadian cities.

In the hydropower sector, utilities in several provinces plan to develop new hydropower power projects, resulting in thousands megawatts of additional electricity.

The Canadian mining industry remains strong and it is known throughout the world in hard rock exploration. Many of the mining methods have been passed on to civil engineering projects throughout the years.

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