Risk Assessment and Mitigation for the Construction of Pedestrian Tunnels and Underground Subway Loop in Downtown Toronto

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1. Introduction
Cut-and-cover underground construction in urban areas has several risk factors. Systematic risk assessment during the design and pre-planning stages helps to mitigate potential risks and some of the adverse impacts of construction.

Through the brief introduction of the scope and technical details of the underground structures completed, this paper reveals the characteristics of working on cut-and-cover tunnels in Toronto’s downtown financial and tourist districts.

Based on the experience learned from working on these projects and on several subsurface cut and cover structures, the authors provide a summary of the risk assessment processes and the typical risk factors and measures taken to mitigate their impacts during construction.

2. Cut and cover tunnels built in Downtown Toronto
The following projects involved the construction of cut and cover tunnels to provide either pedestrian access or public transit system access in areas with high volume of pedestrian and vehicular traffic. Some of the pedestrian tunnels further expand Toronto’s downtown network of tunnels, passageways and subsurface commercial plazas.

The construction of these facilities resulted in relocation of underground utilities, disruption of pedestrian crossings and short or long term closures of traffic lanes.

2.1 Introduction of the selected tunnel projects

2.1.1 BCE Place – Union Station Pedestrian Tunnels
The tunnels are Y shaped and are located under the intersection of Front Street and Bay Street. They connect the TTC Union Station Subway Station, the Royal Bank Plaza and the Canada Trust Tower in the BCE Place complex.
2.1.2 Commerce Court – Scotia Plaza Pedestrian Tunnel
This tunnel is located under King Street and connects Commerce Court tower to the Scotia Bank Tower. This tunnel is linked to Toronto’s downtown network of pedestrian tunnels.

2.1.3 Manulife Center – Bloor Street Pedestrian Tunnel
This tunnel is located under Bloor Street just west of Yonge Street, two of the City’s major downtown arteries. The pedestrian tunnel connects the Manulife Centre retail concourse to the Holt Renfrew department store.

2.1.4 One Queen St. Pedestrian Tunnel
This tunnel is located under Yonge Street, just south of Queen St. It connects The Bay department store to the Office tower located at south east corner of this busy intersection.

2.1.5 Public transit tunnel for the TTC Spadina – Bloor LRT Loop
This tunnel and Loop are located at the intersection of Bloor and Spadina Streets and extend to the Spadina TTC station located north of this intersection. The tunnel is approximately 400 m long with a loop at the intersection giving it a P shaped horizontal configuration.

The work included the construction of reinforced concrete single and double track tunnels, access elevators and ventilation shafts. This work also included the demolition of the exterior walls of the existing subway station and the construction of a new platform to provide Light Rapid Transit access to the subway station.

2.3 Brief description of the construction procedures and challenges

2.3.1 Relocation of underground utilities located within the tunnel. This includes relocation of water mains, sewer lines, electrical duct banks, telephone lines, steam pipes, etc.

2.3.2 The cut and cover tunnelling method was used during construction. Shoring, decking and excavation works were followed by underground utility support and relocation.

2.3.3 Traffic flow had to be maintained at all times. This was accomplished by constructing a combination of steel and timber decking.
2.3.4 Installation of piling and lagging shoring system to provide a safe excavation and lateral support of adjacent lanes and utilities. The piling system also served to provide the support for the temporary decking. Heavy drill rigs and cranes were required during the installation of the shoring systems. This equipment had to work in tight spaces in close proximities to heavily travelled streets and sidewalks.

2.3.5 Staged traffic closure. A minimum of one traffic lane had to be maintained at all times. This required temporary lane closures and night work to provide access to the work area.

2.3.6 The tunnels were relatively shallow. The bottom of the tunnels was approximately 5m below grade and the top of the tunnels was as shallow as 0.5m below grade.

2.3.7 Utilities and temporary traffic decking had to be installed above the top slab of the tunnels to allow for the construction of the roof slab. Other utilities had to be relocated to below the bottom slab.

2.3.8 The tunnels were constructed from cast in place reinforced concrete slabs and walls. Staged traffic, lane closures, daily removal and reinstallation of the decking was required during the excavation, formwork, rebar installation, concrete placing and finishing works. The EFCO Super-stud system or similar systems were utilized to achieve the one sided wall formwork. Most of the tunnel walls are cast against the lagging shoring system.

2.3.9 The TTC tunnel width varied from four metres for a single track, to eight metres for a double track. At the street intersections and under traffic lanes the six metre high reinforced concrete walls and roof slabs were built under the timber decking supported by the steel beams.

2.3.10 Siphon chambers were built 8m below street levels to connect the storm and sanitary sewers being replaced before the tunnel structure was built.
2.3.11 Most of these tunnels included high-quality architectural finishes featuring marble or granite walls and floor surfaces as well as stainless steel or bronze cladded glazed doors.

Figure 6 – Caisson wall and shoring to support adjacent buildings along TTC Spadina Station

3. Risk assessment and mitigation for cut and cover construction

3.1 Risk assessment – result, timing, collaboration

The cut and cover construction procedure for underground structures is dependent on the function, location, size and complexity of the proposed facility. Logistics utilized during this process will vary accordingly. Construction of tunnels and structures located in densely populated urban areas that include a network of surface transportation routes and subsurface public utilities has several typical risk factors. Thorough risk assessment during the design and construction planning stages will identify and consequently mitigate the impacts of the cut-and-cover construction procedure.

The risk assessments shall commence before the work starts on the project design. The conclusions, considerations and method selections resulting from the analysis will be incorporated in the design. Other risk elements related to the interface between construction and the urban environment are investigated at the construction pre-planning stage.

At the design and development stages, the consulting engineer prepares the initial risk assessments for the owner’s review and consideration. The contractor’s risk assessment is developed at the tendering and construction planning stages. The ideal approach is for all the stakeholders to participate in this process from the conceptual design stage. This collaboration among all the stakeholders is dependent on the selected delivery method for the project (design-bid-build or design-build.)
The projects presented above were completed on a standard design-bid-build contract basis and the owner’s design has included several aspects of the risk mitigation measures: evaluation of geotechnical conditions; constrains related to the specific urban environment; design of utility relocations; selection of excavation support systems; requirements of street decking; requirements for vehicular and pedestrian traffic. The contractor had to incorporate the above factors in developing the work plans, schedules and construction procedures and techniques.

3.2 Review and Interpretation of the geotechnical information

Availability of detailed and reliable information of soil, rock and groundwater conditions in the work area is fundamental for proper planning of the underground operation and for reducing the risk to a manageable level. For the presented projects the tunnels were shallow and the subsurface soils were previously disturbed by underground utilities construction. Sufficient geotechnical information was available to design and construct a safe shoring system. Proper evaluation of the geotechnical engineering report will alleviate the risks associated with the design and construction of an adequate shoring system and temporary supports for adjacent structures.

3.3 Mitigation of risk factors related to urban environment

Understanding of the existing environmental conditions and the potential impacts of construction to the surrounding urban area is imperative. To minimize the adverse impacts of construction, the following common risk-mitigation measures shall be considered at the planning of cut-and-cover operations:

- Prevention of surface settlement and lateral movements of adjacent subsurface soils to minimize the risk of damages to buildings, structures, pavements and driving lanes.
- Proper sequencing of the utility relocations will minimize the disturbance of critical utility operations.
- Maintaining vehicular, public transit and pedestrian traffic through the installation of temporary steel and wood decking, providing lane diversions or detours and protected pedestrian walkways.
- Protective measures to preserve the ‘quality of life’ in the city as much as possible, such as vibration and noise control, limitation of working hours and noisy operations near residential or sensitive buildings, dust and pollution control, maintaining accessibility for emergency vehicles etc.
- Setting up and operating a public information system for the communities affected by the construction.
• Prevention of: air, rock, soil and groundwater pollutions; surface water pollution; and disturbance of green areas and parks.

3.4 Risk Assessment for Selection of Construction Methods, Equipment and Logistics

The comprehensive risk assessment and pre-planning shall establish the construction sequences, applied techniques and logistics, and review the impacts of those on the urban areas and the environment. The selected methods and equipment shall be compatible to the various environmental constraints, as well as to the specific site and soil conditions for preventing major problems and risks during the construction.

Cut-and-cover method for constructing tunnels does not require special tunnelling type techniques – Construction is carried out with common building construction techniques.

• The first stage of the cut-and-cover construction requires the removal and relocation of utility service lines with temporary traffic closures or detours. Traditional excavators, trenchers, directional drilling, demolition and paving equipment etc, can be used for this stage.

• To create an underground enclosure for the subsurface structures, traditional excavation support methods are utilized. These include soldier piles and lagging, sheet piling, diaphragm (slurry) walls, secant pile (caisson) walls, soil treatments and jet grouting.

• The selection of excavation support systems at the planning stage is based upon several critical factors, such as: soil and groundwater conditions, location, loads and state of buildings, roads and public utilities around the excavation and others constraints imposed by the urban environment.

• Prevention of soil movement is accomplished by the tunnel reinforced concrete elements: base slabs, walls and roof slabs. During the excavation works, temporary or permanent shoring systems are utilized. Caisson walls are not practical in areas with large number of underground facilities crossing the tunnel. The handling and supporting of underground utility lines makes the drilled steel soldier piles and wood lagging shoring system more practical. This system was utilized in the construction of the aforementioned tunnels.

• The risk factors at the construction of structural, architectural elements and mechanical/electrical services in the cut and cover tunnel are similar to the risks considered at general construction works.
3.5 Detailed Pre-planning of Construction Based on the Results of Risk Assessment Process

When the basic sequencing, techniques and logistics have been established and urban environmental constraints have been clarified and addressed, the last stage of the process is the preparation of planning documents for the cut and cover construction. The main elements are:

- Construction staging plan.
- Environmental protection plan including all the monitoring requirements.
- Plan for the sequencing of utility relocation, removal or construction.
- Traffic control plan with traffic signs, lights and barricades by stages.
- Temporary roads, public traffic routes, pedestrian crossings and protection.
- Site lay-down, access routes, hoisting and protection plan by stages.
- Excavation support and excavation plan, access and haulage routes by stages.
- Resource loaded construction and milestone schedule, incorporating the stages.

These documents are inter-related and shall be coordinated during planning and construction.

4 Conclusion

After a brief introduction of several cut-and-cover tunnels built in Toronto’s downtown financial and tourist districts, the authors emphasized that pre-construction efforts help the prevention and mitigation of most of the potential risks thus exploring best solutions for challenging subsurface works.

A systematic risk assessment process at the design and construction planning stages is very important. The best option is for all the stakeholders to be involved in the process from the conceptual stage. The contractor’s value engineering and practical experience will have an added benefit in managing and mitigating the potential risks.

Collaboration and balanced risk sharing between all the stakeholders will significantly improve the success of the complex cut and cover tunnelling projects.

*Figure 9 – New platform for transfer to the TTC lines*