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# Advance Tunnel for Scarborough Subway Extension, Ontario Canada Case History – Early Works to TBM Launch

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ABSTRACT

The Advance Tunnel for Scarborough Subway Extension (ATSSE) was awarded by Metrolinx and Infrastructure Ontario, the Contracting Authority, to Strabag Scarborough Project Inc. (Strabag) on May 25, 2021; as a Design, Build, Finance project.

The Scarborough Subway Extension is a 7.8km long extension to the existing Toronto Transit Commission Bloor-Danforth Line 2. The project consists of a large diameter single bore tunnel from Sheppard Avenue East and McCowan Road to Midland Avenue and Eglinton Avenue East. The tunnel is to be constructed utilizing an Earth Pressure Balance (EPB) Tunnel Boring Machine (TBM), that will install a 10.7 m internal diameter Precast Concrete Tunnel Liner (PCTL), through the varying geological conditions found along the alignment. Along with the tunnel, watertight launch and retrieval shafts as well as headwalls for future stations and emergency exit buildings are also to be constructed. Once completed, the tunnel will house two trains within this single tube and will be the largest diameter metro tunnel in Canada.

First, this paper will describe the owner-led initiatives undertaken prior to contract close, which included the geotechnical investigation work, advance utility relocations and other pre-construction activities. Second, we will discuss the contracting approach with Strabag, which employed an approach not previously taken for a P3 transit project in Ontario, which included an early works agreement to enable start of TBM manufacturing, demolition of existing structures and preparations for start of secant piling at the launch shaft prior the main contract award. Third, we will explore in more detail the TBM specifications, factory acceptance testing, and delivery to site. Lastly, we will discuss the construction of the watertight launch shaft and TBM assembly in said shaft.

## 1 INTRODUCTION

The Advance Tunnel for Scarborough Subway Extension (ATSSE) is a 7.8km long extension to the existing Toronto Transit Commission (TTC) Bloor-Danforth Line 2. The project consists of a large diameter single bore tunnel that commences at the intersection of Sheppard Avenue East and McCowan Road (main compound and launch shaft site), the alignment then continues southerly under McCowan Road and then curves westerly on Eglinton Ave, to the location of the retrieval shaft at the intersection of Midland Avenue and Eglinton Avenue East. The tunnel will be constructed utilizing a large diameter Earth Pressure Balance (EPB) Tunnel Boring Machine (TBM). The TBM will install a Precast Concrete Tunnel Liner (PCTL) that will act as the primary support and final tunnel. Along with the tunnel and watertight launch and retrieval shafts, headwalls at future station locations as well as future Emergency Exit Buildings (EEB) are also to be constructed. Once completed, the tunnel will house two trains within this single tube and will be the largest diameter metro tunnel in Canada.

## 2 PRE-CONSTRUCTION SCHEDULE ACCELERATION

To accelerate the SSE project delivery, the contracting authority elected to deliver the under two distinct scope packages: the first a Design Build Finance (P3) package for the delivery of the Advance Tunnel or “ATSSE”; the second package a Progressive Design Build for the delivery of the stations, tunnel fit-out, systems installation and commissioning, which will be a future release known as the “Stations, Rail and Systems” or “SRS” contract. Figure 1 shows the scope split between the two packages.

The ATSSE procurement deployed a standard Request for Qualifications followed by a Request for Proposals (RFP) process. The RFP period included a series of interactive meetings between the Contracting Authority (CA) and the three shortlisted proponents where the Reference Concept Design (RCD) was utilized for proof of concept and conceptual design. This procurement process was a joint collaboration and the Technical Advisor, 4Transit (a Joint Venture consisting of WSP Canada Group Ltd., Hatch Corporation, and Parsons Inc.), supported the CA in the development of this phase.

To achieve the desired schedule, the CA decided to continue to fund the advancement of critical design during the RFP process and then employ the use of an ‘Early Works Agreement’ to mobilize the First Negotiation Proponent in immediate design and site works.

The successful proponent was the joint venture of Strabag and ARUP. The joint venture would be responsible for the execution of the Project Agreement (PA) and developing the final design and executing the overall works.


*Figure 1: SSE Contract Breakdown*

To further de-risk the project a pre-construction schedule acceleration program was undertaken by the CA to initiate some key works along the alignment, and effectively accelerate the schedule of the entire ATSSE contract by completing much of these key-works prior to Financial Close of the project.

Some of the accelerated key works included: Permitting, Utility Relocations, Property Acquisition, Geotechnical Investigations and the development of a Geotechnical Baseline Report (GBR). Each of the identified key areas were undertaken by the CA in collaboration with the CA’s Technical Advisor, OneT+, a joint venture partnership between Gannett Fleming Canada, IBI Group and GHD. OneT+ would provide technical advisory, and other services to support the overall planning, preparation, procurement and construction of the project prior to, and after, Financial Close.

### 2.1 Permitting

The Metrolinx Permits, Licenses and Approvals (PLA) Team worked closely with various Authorities Having Jurisdiction (AHJ) to start the permitting process and/or obtain specific permits in an effort to de-risking the project, accelerate schedule and allow the constructor to hit the ground running with respect to their construction activities. The team worked closely to prepare applications, engage AHJ staff, prepare responses to comments, update / revise technical reports to address AHJ comments, keep the SSE Senior Management Team (SMT) appraised of the status regularly, and ultimately secure the necessary permits. In certain instances, a two-stage approach was used with specific AHJs, such as the Ministry of the Environment, Conservation and Parks (MECP) for the Permit to Take Water (PTTW) and Toronto Water (TW) for the Sewer

Discharge Permit (SDP). This process allowed the CA to obtain Stage 1 approval and would assist the constructor in achieving and expedited Stage 2 approval. The ATSSE project was also the first to use code consultant to review the demolition plans for compliance with the Ontario Building Code. The following permits were obtained in advance:

- Demolition Permits for Launch Shaft 1 (LS-1)
- Tree removal permits for boundary trees
- Stage 1 Permit to take water for LS-1 (Launch Site)
- Stage 1 Sewer Discharge Permit for LS-1 (Launch Site)
- Stage 1 Permit to take water for LS-2 (Retrieval Site)
- Stage 1 Sewer Discharge Permit for LS-2 (Retrieval Site)

## 2.2 Utility Pre-Construction Services

The Metrolinx Pre-Construction Services (PCS) (Utilities) Team developed a program for disconnections, relocations, and upgrades to existing infrastructure along the proposed alignment, held by local utilities to accommodate the SSE design. Initial discussions with each of the utility providers: Toronto Water (TW), Toronto Hydro-Electric Systems Limited (THESL), Enbridge Gas, Rogers Communications, Bell Communications and Beanfield, were held to identify infrastructure conflicts and new designs for relocations / accommodation for SSE were explored. Agreements were reached with each provider who then worked with their identified contractors in an aim of completing of the work prior to work being started by the ATSSE constructor at each location; in hopes that it would allow them to timely access to start work without having to perform certain relocations as part of their scope.

In addition to the above, and after having possession of both LS1 and LS2 sites, Metrolinx internal Project Delivery Team (PDT) had undertaken the disconnection of telecommunications, and utility services at said locations prior to handing over the properties to the constructor.

## 2.3 Property Acquisition

During the development of the RCD, specific properties were identified for expropriation / acquisition in order to facilitate the advance of the ATSSE project. The first properties along the alignment to be identified for acquisition were the LS-1 and LS-2 sites, that would be required for construction of the launch and retrieval shafts.

Metrolinx is responsible for both the acquisition and expropriation of lands and temporary and permanent easements along the identified tunnel alignment to ensure that the TBM was able to tunnel under both private and City of Toronto (CoT) Right of Way (ROW) lands.

This process has been initiated in 2020 and was timed to coordinate with the schedule for the tunnel procurement. The tunnel alignment was situated, for the most part, directly underneath the ROW lands in order to minimize disruption to private property owners (both commercial and residential).

The SSE was also the first project in Ontario to utilize the new Building Transit Faster Act (BTFA) to minimize delays in the acquisition of properties, usage of properties along the alignment for due diligence purposes and provided Metrolinx with the necessary tools to acquire the necessary lands. This process was used where multiple attempts to achieve an amicable agreement with property owners was not possible, and the properties were required in order for works to progress.

## 2.4 Geotechnical Investigations

Metrolinx, in collaboration with the Technical Advisory teams and Golder Associates had undergone a geotechnical investigation program at the proposed launch and retrieval shafts as well as along the proposed tunnel alignment. This geotechnical investigation was used to create a Geotechnical Data Report (GDR) and to a Geotechnical Baseline Report (GBR); that would be representative of the geotechnical conditions to be anticipated. This GBR had been provided to all the proponents during the tender process and allowed for each proponent to review, make comment, and ultimately select the methodology used for excavation of the shafts, headwalls, and the design development of the type of Tunnel Boring Machine (TBM) that would be utilized.

For the most part, the geotechnical conditions that would be encountered during the construction of the project are described below, commencing from the surface elevation to well below the invert depth of the tunnel, as follows:

Class A: Layers of topsoil ranging from approximately 0.3 m to 0.5 m thick, encountered where boreholes were advanced through landscaped areas. Fill encountered along the alignment is composed of sand and gravel to silty clay extending to depth ranging from about 0.1 m to 10.1 m.

Class B: Granular soil deposits ranging in gradation from sand and gravel to sands, encountered along the entire alignment either as isolated discontinuous layers or as continuous layers of greater horizontal and vertical extent and are often present above/below non-cohesive till soils. Granular deposits exhibit significant variation in thickness from approximately 0.3 m to about 26 m.

Class C: Well to poorly graded cohesive (plastic) clayey silt to granular (non-plastic) silt are encountered continuously along some portion of the alignment with a thickness range of 1 m to about 20 m.

Class D: Other soils deposits that consist of broadly graded cohesive (plastic) soils such as clayey silt to silty clay (containing cobbles and boulders) is encountered below and within the tunnel invert.

Class E: Deposits of broadly graded non-plastic zones of brown to grey silty sand to sandy silt (containing cobbles and boulders) where present and encountered near surface along the entire alignment with a range in thickness of less than 1 m to 46 m. Figure 2 is an example of a near surface boulder that was found during the excavation of the launch shaft. This boulder was approximately 1.2 m (48inch) in width. Boulders encountered during the excavation were documented and were within the size range described in the GBR.

No bedrock was anticipated to be encountered within the excavations or along the tunnel alignment. See Figure 3 and Figure 4 for the stratigraphic soil profiles developed in the areas of the launch and retrieval sites.

*Figure 2: Boulder excavated at Launch Site*

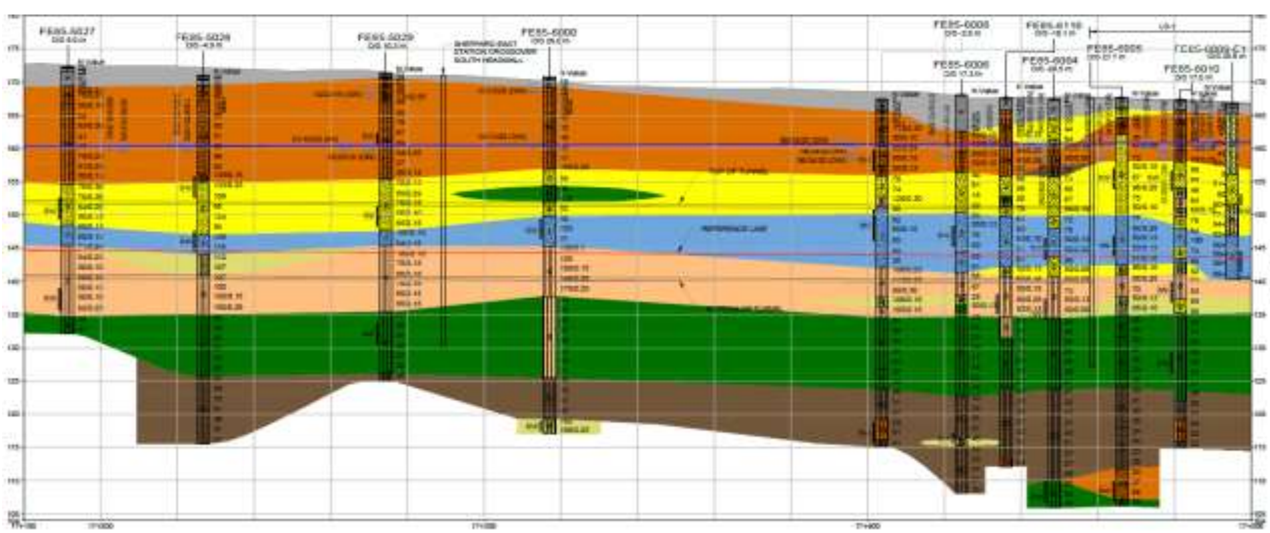

*Figure 3: LS1 Stratigraphic Soil Profile*

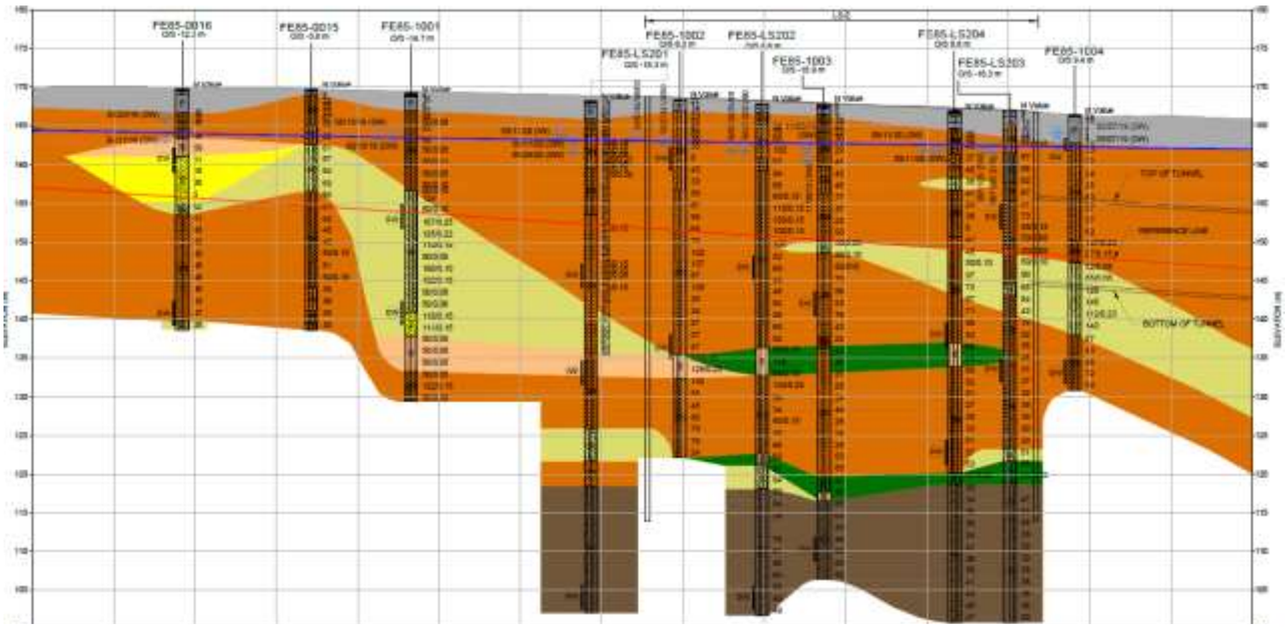


*Figure 4: LS2 Stratigraphic Profile*

| | |
|---|---|
| Number of Boreholes: | 366 No. |
| Number of Monitoring Wells: | 575 No. |
| In-Situ Hydraulic Conductivity Testing: | 11 Pump Tests<br>411 Well Response Tests |
| Pressure Meter Testing (PMT): | 67 No. |

Table 1: Quantity and Type of Geotechnical Investigations

### 2.4.1 Obstruction Investigation

As part of the geotechnical investigation program, investigations of manmade objects along the tunnel alignment were also undertaken to reduce the risk of impact with the TBM during tunnelling operations. This included a historical review of architectural, engineering, as-built drawings of buildings where possible tiebacks could interfere; as well as physical investigations where Ground Penetrating Radar (GPR) and hydrovac techniques were employed. Of all the investigations, a single area was identified (100 Consilium Place) where the tunnel came within proximity of the property and tiebacks possibly could be encountered. As is an all too common issue, record drawings of the building were unable to be easily located which created the need for the physical investigation. Upon completion of the investigations, drawings for the building's foundation were found and reviewed, and no tiebacks were shown in any of the drawings or details.

## 3 EARLY WORKS

In order to facilitate early mobilization, the First Negotiation Proponent (FNP) "Strabag" was able to progress certain activities between their announcement of FNP and prior to Financial Close (May 25, 2021); through an Early Works Agreement (EWA). The EWA outlined what works could commence prior to Financial Close, which were restricted to: mobilization activities, survey and site investigations, setting up sites, grading and clearing, additional utility and geotechnical investigations, permit applications, and building demolition. Strabag was also about to progress design works and works submittals. The TBM procurement was already underway during the RFP stage, and the Precast Concrete Tunnel Liner (PCTL) procurement, along with other subcontractor agreements were allowed to progress. If for whatever reason, commercial and financial close were not to proceed, Strabag would be reimbursed for the direct costs incurred for these particular activities.

## 3.1 Tunnel Boring Machine early procurement

Contracting Authority allowed for the preliminary design of the Tunnel Boring Machine (TBM), as well as procurement of long lead items, to be undertaken by the proponents during the in-market period. This would allow for the TBM engineering to advance and would allow for a shorter lead time for the TBM delivery. The successful proponent, Strabag, selected the German TBM manufacturer Herrenknecht (HK) as their supplier of choice. Herrenknecht, headquartered in Schwanau, Germany started the design of the larger diameter Earth Pressure Balance (EPB) TBM, and had placed orders for long lead items such as the main bearing, drive motors, and electrical components which would allow them to manufacture the TBM in record time.

# 4 TUNNEL BORING MACHINE SPECIFICATIONS

Strabag elected to purchase the large diameter EPB TBM from Herrenknecht because of their experience and success in the manufacturing of large diameter EPB TBMs used on projects globally. Strabag also had a long history with HK and had purchased over 20 TBMs from the manufacturer previously. The TBM selected was an 11.9 m diameter, mixed face, Earth Pressure Balance (EPB) TBM, designed to handle the geological conditions which were to be encountered along the ATSSE tunnel alignment. The TBM would be designed to erect the specified 10.7 m internal diameter PCTL, which would allow for the single bore twin rail design. Table 2 outlines some of the other TBM specifications.

| | | | |
|---|---|---|---|
| **TBM Cutting Diameter:** | 11,910 mm | **Max unlocking Torque:** | 43,711 kNm |
| **TBM Weight:** | 1,500 t | **Propulsion Cylinders:** | 48 No. x 2,155 kN |
| **Overall Length:** | 71 m | **Total thrust:** | 103,440 kN |
| **Cutterhead Type:** | Mixed Face | **Screw Conveyor Dia:** | 1,400 mm |
| **Disc Cutters** | 54 No. x 483 mm dia. | **Screw Capacity:** | 1,800 $m^3$/h |
| **Main Drive Type:** | Electric VFD | **Segment Erector:** | Vacuum pick up |
| **Main Drive Power:** | 16No. x 350kW = 5600kW | **Primary Voltage:** | 13.8 kV |
| **Main Drive Speed:** | 0 – 2.6 rpm | **Transformers:** | 2 x 3,500 + 2,000 kVA |
| **TBM Airlock** | 2 chamber | **Total Installed Power:** | 6,750 kW |
| **TBM Material lock** | 1 | **Annular Void Grouting:** | 2 component (A + B) |
| **Tunnel Guidance** | VMT system | **Ground Conditioning** | yes |
| **Probe Drill and Ports** | Yes | **Automatic Bentonite** | Plenum injection |

Table 2: TBM Specifications

## 4.1 Factory Acceptance Testing

Factory Acceptance Testing (FAT) of the TBM was performed at the HK factory on September 27 & 28, 2021; in the presence of the client, Strabag, as well as a representative form the CA. FAT was to confirm testing of all TBM functions (mechanical, electrical), conformity to Canadian standards, to document outstanding elements and to identifying non-conforming parts and/or systems. The TBM was ready for FAT only 5 months after Financial close, and this was due primarily to the success of the early engagement with the TBM manufacturer that the CA allowed for. Overall, the tests were successful and Strabag signed off on the FAT. Within two weeks of FAT, the TBM was already being disassembled and prepared for transport to site. See Figures 5 and 6 for TBM photos at the HK facility


*Figure 5: TBM with Project Branding*


*Figure 6: TBM FAT photo with SB, CA, HK present*

4.2 TBM Transportation to site

Following FAT in Germany, the TBM was disassembled and prepared for transportation. The TBM had to be transported by river barge on the Rhine River to Dutch port at Westdorpe, where it would then be loaded onto a large cargo ship “Jumbo Vision”. Jumbo vison departed on November 26, 2021, on its sea voyage and arrived in the Port of Oshawa, Ontario in mid-December. After arrival in Oshawa, the TBM was transport by truck to the LS1 launch site in Scarborough, Ontario. The transport of the TBM and ancillary components included 65 No. Bulk Loads, and 85 No. Container Loads.


*Figure 7: TBM being offloaded from Jumbo Vision at Port of Oshawa, Ontario*

*Figure 8: Photo of TBM component layout on Jumbo Vision transport ship*

5 LAUNCH SHAFT (LS1)

The project agreement specified that the TBM main launch shaft was to be constructed as ‘water-tight’; as defined in Haack’s water tightness criteria 1991 – Tightness class 3. The design also called for requirements with respect to maintaining stability of the shaft faces for TBM launch and breakthrough, size requirements, as well as limits to the use and type of internal bracing that had to be adhered to. The Launch shaft was constructed using a watertight secant pile method, and specifications with respect to size, verticality and interlock criteria had to be met. Once the secant piles along the perimeter of the shaft were constructed, the shaft would be excavated, and tiebacks would be installed at each level of excavation. The secant piles around the perimeter were composed of filler piles and structure king piles. The king piles contained two steel beams within each pile, that were connected by a pipe flange welded in between the two beams at the position of the future tie-back to be drilled. Special hybrid structural elements were used for the king piles located in the location of the tunnel eye. They consisted of a steel-fiber-steel pile, where the fiber was located in the area of the TBM bore so that the machine could mine through the fiber. A similar type of pile was used at the location of the headwalls that were to be constructed along the alignment for the future stations and emergency exit buildings. Strabag choose GFL as their shoring contractor for the shafts and headwalls. The launch shaft dimensions are approximately 28m in width, 80m in length, and 26m in depth.

*Figure 9: Secant Pile Drill Rigs at LS1 Site*

*Figure 10: Tieback Drill Rig utilized at LS1 site*

5.1 TBM assembly in shaft

In the project agreement, the contractor was incentivized to complete the launch shaft and install the TBM in said shaft by a specific date, April 29, 2022. The contractor was assembling the TBM on the surface simultaneously as they were completing the launch shaft. In order to install the TBM within the shaft, a very large Mammoet Gantry crane had to be assembled on the north side of the shaft and it extended into the launch shaft itself. The gantry crane had a lift capacity of 2000 metric tonnes and was going to lift the TBM as one unit and lower it into the shaft. A second lift would be required to lower the TBM cutterhead in front of the TBM so it could be mounted in shaft. The contractor was able to achieve the assembly incentive by the required deadline. The figures below show the Mammoet Gantry Crane, the TBM unit being lowered, and the TBM completed in the shaft.

*Figure 11: Mammoet Gantry Crane*

*Figure 12: TBM Being lowered into LS1*

*Figure 13: TBM at LS1 bottom*

# 6 CONCLUSION

The model utilized by the Contracting Authority to advance the utility relocations, acquire properties, perform geotechnical and environmental investigations, and apply for permits allowed the successful Design, Build, Finance team to hit the ground running. The implementation of the early works program and commencement of works to progress ahead of the ATSSE financial close proved to be beneficial to the schedule. This allowed the work to be started close to a year before award and this advanced work allowed for the compressed schedule to be a net benefit for the project. At the time this paper was written, the TBM and Gantry #1 were advanced to the south wall in preparation for launch, the site and TBM power supply was in place, and the construction of the headwalls was underway as well as the works at LS2 which includes a road relocation. CA and Strabag continue to work together to advance the works along the project alignment, and to work with all stakeholders involved.

Continued collaboration, between all parties, will promote and lead to the successful completion of this project.

*Figure 14: TBM and Gantry 1 in shaft*

## 7. REFERENCES


Walters, D., Palmer, S., Boone, S., and Lacchin, D. 2021. *Geotechnical Baseline Report Advance Tunnel Contract for Scarborough Subway Extension, Rev 6.*

Photos provided by Strabag Canada / Metrolinx Project Delivery Team.

*Project Agreement – To Design, Build and Finance the Advance Tunnel for the Scarborough Subway Extension* between Ontario Infrastructure and Lands Corporation, Metrolinx, and Strabag Scarborough Project Inc.