DFI-Use of Structural Slurry Wall for Permanent Structures
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PERMANENT SLURRY WALLS USED IN TORONTO'S DEEPEST SHAFT TO FIX THE COXWELL EMERGENCY BYPASS

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Background

In the late 1950s, to facilitate the expansion of the city of Toronto a 2.6 m ID trunk sewer was installed connecting northern sections of the city to the treatment works by the lake. At that time, this was tricky undertaking with excavation by hand through water-bearing alluvial materials. Tunnel depths were up to 45m and compressed air was utilised as support.

Existing Coxwell Trunk Sewer – Circa 1960 – Toronto Archives

As part of the environmental assessment for future expansion work, video inspections discovered a damaged section within the Coxwell Trunk sewer. The damaged section was close to residential properties and was of obvious concern to the City of Toronto. The City of Toronto considered it prudent to affect a repair to this section as quickly as possible. With the system running close to capacity, it was not possible to enter and

repair in a reliable and cost-effective manner, and consequently, an emergency bypass tunnel was designed.

The bypass involves a short section of equivalent size tunnel running 500 m around the damaged section of sewer. The tunnel will be driven in full EPB as a one pass system with a precast concrete segmental liner, utilising
McNally Construction Ltd. was the successful proponent for the $30M Canadian contract. The contract is a design-build with Aecom Canada as the Designer and Hatch Mott Macdonald acting as project managers for the City.

McNally selected a 3.3 m diameter Lovat EPB tunnelling machine to bore the 2.744 m internal diameter tunnel.

The contract includes two shafts. The northern shaft or TBM entry shaft is located in the existing Don River Valley and is 9 m deep. A secant pile shaft was formed at this location. The route of the tunnel takes it under the sloping sides of the river valley and terminates at the existing sewer at the exit shaft 45 m below ground.

This paper concentrates on the sinking of the 47 m deep slurry wall shaft at the exit shaft location.

The Challenges

Environmental / Social issues

The Tunnel route terminates at the exiting sewer 45 m below ground. This deep exit shaft is located within a very small parcel of land at the top of the ravine with the site hoarding siting on the property line of an adjacent residence. The outside wall of the residence is only 1.5m away from the wall of the slurry wall shaft.

While the City acknowledges that construction always has an effect on a neighbourhood. The disruption to local residents is to be kept to an absolute minimum. To alleviate these issues regular information is issued keeping residents aware of constriction progress. Figure 1 shows the general site compound and its limited area, making the work most challenging.

Figure 1. General site at the Exit Shaft location.

Geotechnical Issues

The geology at the exit shaft consists of glacial deposits with a thick till layer overlying sands and silt. The existing sewer is within the sand deposits. As the exit shaft facilitates the connection of the bypass to the existing sewer, it was necessary to form the slurry wall shaft around the existing sewer. Hydrostatic heads are around 10m.

Locating the existing sewer at the downstream end of the new tunnel was also a challenge due to its great depth and lack of reliable as-built information.

The Final Connection

The bypass must connect into the existing “live Coxwell trunk sewer, which can surcharge to 3m above the tunnel under wet weather flow. The slurry walls panels extend below the sewer on either side, but letter box around the sewer. These spaces must be fully sealed before progressing with the excavation. To facilitate this, a programme of jet grouting from with the partially excavated shaft will be carried out.

Slurry Wall Construction

Tender documents showed a rectangular shaped exit shaft with internal bracing. The shaft was shown as a temporary earth retaining structure, which would have required a final liner wall. As an alternative, Petrifond presented a design-build octagonal shaped shaft, which invariably eliminated the use of any internal bracing. The shaft was also design as a permanent foundation wall, eliminating the need for the final liner wall. This proved to be both economical and improved the construction schedule.

The Exit Shaft presented some challenges for the slurry wall construction and included the following:

1. Construction of a slurry wall over a live sewer without knowing its exact location.
2. Limited vibrations to be induced on the existing sewer from slurry operations.
3. Occupied residence located immediately adjacent to the shaft
4. Geological conditions presented dense to very dense glacial till.
5. Very small site footprint located at a corner of a busy intersection, making construction logistics challenging.

The design build slurry wall shaft has a total depth of 47M of which 42M will be exposed once the shaft bottom is reached. The design was presented to Aecom Canada and City representatives for approval. The shaft layout is shown in Figure 2.

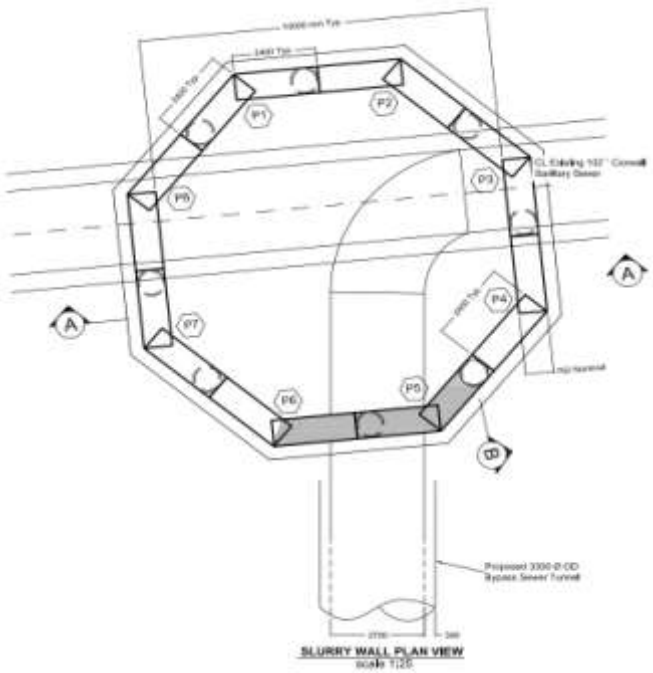

Figure 2. Slurry Wall layout

The choice of equipment stemmed from the project challenges mentioned. In addition, panel alignment and verticality are the most essential elements for a successful result in a circular shaft. As such, to excavate panels to a depth of 47 M, Petrifond decided to utilize a hydraulic pile rig equipped with specialized hydraulic clamshell buckets. The KRC Casagrande hydraulic clamshell bucket is fixed to a rigid Kelly bar enhancing vertical excavation tolerance through the dense soils. In addition the clamshell piston offers a closing force of 200-Ton, which was required to overcome the very dense till matrix. Figure 3 shows excavation rig slurry wall equipment excavating at the Shaft.

Figure 3. Slurry Wall rig used to excavate the panels.

At the outset, concrete guidewalls were constructed to facilitate proper vertical and horizontal alignment for slurry wall excavation. The guidewalls also prevented soil loss near the surface and acted as containment for the introduction of bentonite slurry.

Slurry wall shaft was constructed using 8 panels with a nominal wall thickness of 800mm. Panel joints were constructed using pipe stop-ends, extracted with specially designed hydraulic jacks.

During panel excavation, panel verticality and continuity was continuously monitored with the Koden. Verticality readings of the same joint obtained from two adjacent previously poured panels were compared for deviation, if any, the panel verticality was corrected. Just prior to placement of concrete, the bentonite slurry was cleaned to achieve a sand content below 5%. The shaft exposed to 100-ft depth is shown in Figure 4.

Figure 4. Slurry wall shaft exposed to 100-ft depth.

Because of the extremely limited site space, reinforcing cages were prefabricated and stored at a compound located at the Entry Shaft. The rebar cages were then delivered as required to suit the concreting operations. Concrete ready mix trucks were stationed at a nearby parking lot and on queue for delivery to the panel. No more than two trucks at any time were on the site due to the area constraints.

Progress to date

Work on the exit shaft commenced in July 2010. Prior to commencing the shaft it was necessary to remove an existing buried pumping station from the area. This proved no easy task as the structure measure 9m x 9m and was over 8m deep, additionally it was within 3m of the residential property and 6m of an arterial road. This work was completed by the end of August and the sub-contractor, Petrifond, commenced work on the 10m diameter, 45m deep, octagonal slurry wall shaft.

On completion of the slurry wall, the shaft excavation commenced utilising a crane mounted clamshell. This excavation was completed to 10m above the exiting sewer by the end of March 2011 and the Subcontractor, Hayward Baker, commenced work on the jet grout blocks around the existing. At the time of writing jet grouting work was well underway.

Summary
The Coxwell Emergency Bypass presented a unique challenge with respect to the slurry wall. Environmental concerns, public liaison, proximity of residential areas and forming a slurry wall around an exit sewer at an undetermined location, all combined to require a diligent approach.