



RESILIENT INFRASTRUCTURE

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TOP-DOWN CONSTRUCTION OF THE NEW LRT OVERHEAD BRIDGE, KITCHENER, ONTARIO

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ABSTRACT

A new Light Rail Transit (LRT) system is being constructed in Waterloo Region. The first phase of construction is scheduled for completion in 2017 and will connect Conestoga Mall in the City of Waterloo and Fairview Park Mall in the City of Kitchener, a distance of 19 km. The LRT route crosses the existing Conestoga Parkway (Highway 7/8) in Kitchener-Waterloo, requiring the construction of a new structure under the busy freeway. In 2014-15, the Ministry of Transportation, Ontario (MTO) administered the construction of the new single span bridge using a unique top-down construction technique.

The highway was built during the late 1960s and early 1970s and Kitchener-Waterloo was by-passed by a new four-lane freeway now known as the Conestoga Parkway. To accommodate the existing Canadian National Rail (CNR) track which crossed the then new highway alignment, the highway was built-up on 7.5 m of fill. Recently the Conestoga Parkway was widened to six lanes between Courtland Avenue and Fischer-Hallman Road and part of the construction project included the construction of the new LRT Overhead bridge to accommodate two LRT tracks below the existing highway. The LRT crossing posed three significant challenges; first being the 7.5 m embankment, second being the requirement to maintain four lanes of traffic during construction and the third being the close proximity of the existing adjacent CNR Overhead bridge which was offset 22 m from the new LRT Overhead bridge (centerline to centerline).

Traditional bottom-up construction techniques were considered but not preferred due to the extensive excavation and temporary roadway protection works required to construct the new rail crossing. Since the existing CNR bridge was not designed for unbalanced lateral earth loading, significant excavation on both sides of the CNR bridge would also be required. A top-down construction approach using secant pile abutments and a reinforced cast-in-place concrete deck slab was used to create a 12 m single-span, rigid frame bridge to accommodate two LRT tracks. This concept was similar to the Hespeler Road / CPR grade separation project, constructed in 2012, by the Region of Waterloo. A critical aspect of the LRT Overhead design was to minimize the required excavation and impacts to the existing adjacent CNR bridge with less than 11 m of soil between the two structures. The new LRT bridge design considered the future excavation and replacement of the CNR bridge.

In order to maintain traffic on this busy highway, the new LRT structure was constructed in two stages. The first stage included the diversion of four lanes of traffic to the north half of the existing highway platform to permit the south half of the bridge to be constructed and the CNR bridge to be rehabilitated and widened. As previously discussed, the top-down construction approach was selected because it minimizes excavation; but some staged excavation of the existing embankment, adjacent to traffic, was required. To install the secant pile abutments and retaining walls, a level platform was prepared for the drill rigs, approximately two meters below grade which was the approximate top of caisson elevation. A temporary H-pile and lagging protection system was installed between construction stages to accommodate an approximate three meter excavation. The additional one meter excavation would be required following the installation of the secant caissons for the installation of the deck false work and construction of the concrete abutment caisson cap and deck.

Two parallel secant pile abutment walls and retaining walls were constructed using a combination of unreinforced concrete filler caissons and reinforced concrete king caissons. For both types of caissons, steel liners were used to temporarily support the shaft walls to prevent collapsing of the augered holes. Where loose soil was present, the steel liner was inserted during the augering of the shaft. The liner was vibrated out immediately following the placement of concrete. Each hole was topped up with concrete after the liner was removed. The construction of the secant piles involved first augering 760 mm diameter filler caisson shafts to a depth of five metres below the final top of rail elevation and filling with weak (2 MPa) concrete. The total finish length of each filler caisson ranged between 10.7 m and 11.7 m. The filler caissons were spaced at 1600 mm leaving a nominal 840 mm gap between caissons. Secondly, 1200 mm diameter king caissons, also spaced at 1600 mm, were augered by drilling overlapping holes into the weak concrete filler caissons and removing the portion of soil that remained between two the adjacent filler caissons. The king caissons shafts then had a reinforcing steel cage lowered into the hole and filled with normal 30 MPa concrete. The total finish length of each king caisson ranged between 16.7 m and 17.7 m. The depth of the king caissons were determined to provide adequate vertical capacity and to control deflections and stresses in the caissons due to lateral loads.

Once the concrete in the king caissons reached sufficient strength, the additional one meter +/- of excavation was completed. The top of the caisson wall was exposed to allow for the placement of formwork and cleaning of the protruding reinforcing steel. The deck formwork was supported on grade within the approximate two meter space. The concrete abutment caisson cap, deck, barrier walls, etc. were all placed using conventional construction approaches. The remaining highway elements were finalized completing the south portion of the bridge which allowed traffic to be diverted back onto the new south half of the bridge. Construction on the north stage of the bridge was completed in the following construction season, similar to the north portion. The removal of the existing embankment material, between the abutment walls, was carried out following the completion of the bridge superstructure as discussed below.

One of the most significant advantages of the top-down approach is it offers the ability to open the highway to traffic prior to removing the embankment material from inside the structure. This removes many of the substructure elements from the construction critical path. Although the design was set-up to complete the excavation at the completion of both stages, the contractor opted to complete a portion following each stage. The following provides the general sequencing based on the design approach. The pre-determined staged sequence of the embankment material was designed to control the deflections and stresses in the caisson wall during construction.

1. Following the removal of deck formwork, the interior was excavated to an average of five meters below the underside of deck
2. A temporary horizontal shoring system was installed and pre-loaded between secant pile abutment walls (**Figure 1**)
3. The remaining 3.4 m of embankment fill was removed from the interior, approximately 2.4 m below the final top of rail elevation
4. A granular drainage layer and permanent reinforced concrete strut was constructed between the secant pile abutment walls
5. Following the curing of the concrete strut, the temporary horizontal shoring system was removed
6. Reinforced concrete facing walls were constructed on each abutment
7. Granular bedding was placed to the underside of the rail elevation in preparation for the future installation of the ballast, ties and rails.



Figure 1: Photograph of Temporary Shoring System

In summary, the top-down construction approach, using secant caissons, is a feasible technique where there is a need to minimize excavation and roadway protection. The presentation will further discuss the benefits of the top-down construction approach for the LRT bridge and also discuss the design challenges and construction aspects of the project.