West Toronto Diamond

Brent Archibald, P.Eng.
Vic Anderson, MSc (London), DIC, P.Eng.
Joanne Crabb, P.Eng.,ing., PE
Jonathan Werner, M.A.Sc., P.Eng.

Paper prepared for presentation
at the Bridges: Economic and Social Linkages Session
of the 2007 Annual Conference of the
Transportation Association of Canada
Saskatoon, Saskatchewan

Abstract

This paper describes the West Toronto Diamond project in Ontario, Canada. This project has been designed to eliminate at-grade diamond crossings of the Canadian National Railway (CN) and the Canadian Pacific Railway (CPR) tracks in the Junction area of Toronto, an area which takes its name from the confluence of these railways. Since the 1880's, rail traffic here has been constrained by these diamond crossings involving the CN and CPR mainlines and a CPR Wye track. The project will result in a quantum improvement in the levels of service and safety provided by the Railways at this site.

The project involves relocating the CN tracks below the CPR tracks, while at the same time maintaining all rail operations with a minimum of interruption to the Railways' activities. The site is physically constrained and hence, in order to accomplish this goal, Delcan's design includes the sliding of 4 mainline railway bridge spans, weighing a total of some 10,000 tonnes, into their final positions. Each slide occupies only a few hours, as it is powered by computerized high-speed tandem hydraulic jacks, moving these massive structures on steel / aluminum bronze slide paths, enabling the bridge spans to move quickly and continuously into position during brief possessions of the tracks. This is a first in Canada for this specific technology applied to railway bridges.

Delcan's experience in large-scale heavy bridge slides was a key factor in the Railways and GO Transit accepting this unusual technique at the West Toronto Diamond site. This reduced the cost of the project by some $10 Million, and reduced the necessary time of construction by at least 6 months.

The project also is designed to accommodate a remarkable piling method which is called Silent Piling. This method involves the installation of piles with zero vibration, by means of a hydraulic crush piling system. It enables this major deep piling project to be constructed with minimum risk to the environment, as quietly and unobtrusively as possible, and including minimal risk to nearby sensitive buildings, services and utilities.

The Project is owned by GO Transit, who operate a commuter train service on the CN tracks. This approximately $125 Million project will greatly enhance all affected rail operations in West Toronto, hence having long term continuing economic and social benefits for the lifetime of the project in service, which is designed to be over 100 years. This is an example of true sustainability.

1.0 Introduction

The West Toronto Diamond project is owned by GO Transit and is part of the GO TRIP program which focuses on GO Transit expanding their current passenger rail network to address the steady increase in transit ridership due to the steady increase in population within the Greater Toronto Area.

The project consists of eliminating two existing at-grade diamond crossings of the Canadian National Railway (CN) and the Canadian Pacific Railway (CPR) with a one kilometer long grade-separated structure. The CN corridor will be depressed below grade while the CPR tracks will remain in their current location. The CPR tracks at this site are used extensively to haul freight between Toronto and Montreal, whereas the CN tracks, although used for freight, predominantly carry passenger trains operated by GO Transit and Via Rail.

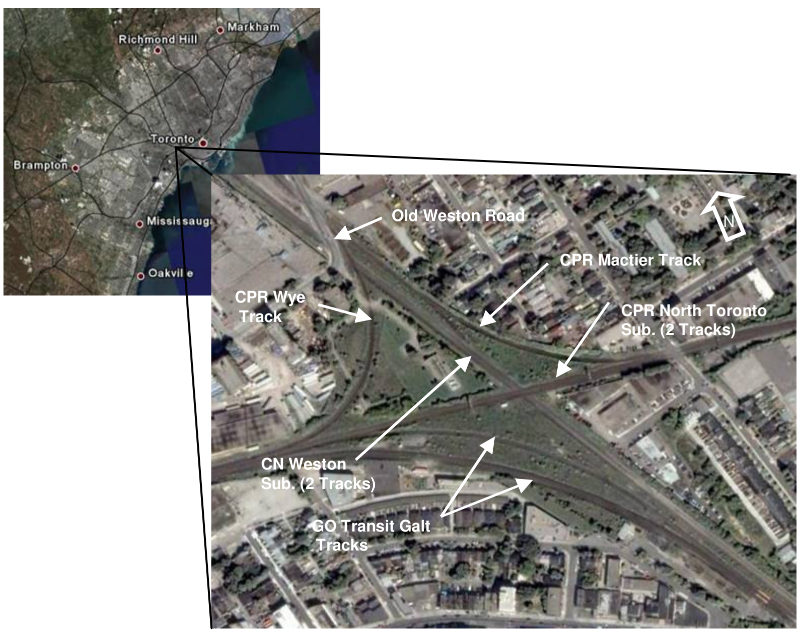

Figure 1 – Location and Existing Site Conditions

The project is located in one of the oldest parts of the City of Toronto, with the original construction of the railway corridors occurring in the late 1800's. The area has been built-up with both industrial and residential properties surrounding the original Railway rights of way.

The current at-grade crossing of the CPR North Toronto and the CN Weston Subdivisions is able to satisfy the current demands of CPR freight and GO Transit passenger trains, but cannot accommodate any future capacity, as a result of increased demands for GO Transit's service on the CN Weston corridor. In addition to GO Transit's service demands, the proposed airport rail link, from Downtown Toronto to the Toronto International Airport, would need to be accommodated on the same CN Weston Subdivision. As a result of these constraints, GO Transit has undertaken to construct a rail-rail grade separation at this site.

2.0 Project Description

The project consists of several components which required special attention due to significant amounts of interaction which generated unique challenges but which also allow the potential for innovative solutions.

The project site is very congested and complicated by the presence of four property owners (CPR, CN, TTR and City of Toronto), four operating railways (CPR, CN, GO Transit and VIA), extensive buried utilities including a 1200 diameter truck watermain, a 1500 diameter combined sanitary / storm sewer, railway signals, and four fibre optic companies' services with main conduits running within the railway corridor.

The existing CN Weston Subdivision consists of two tracks, which intersect the CPR Wye track adjacent to Old Weston Road and the two CPR North Toronto tracks. These CPR corridors are located approximately within 500m of each other. In addition to the CN and CPR tracks, two existing Galt Subdivision tracks connect the CPR and CN Subdivisions and run parallel to the depressed corridor.

Figure 2 – Diamond at CPR North Toronto Subdivision and CN Weston Subdivision

Figure 3 – Diamond at CPR Wye Track and CN Weston Subdivision

The proposed depressed corridor will accommodate up to four tracks (two existing and two future) on the CN Weston Subdivision and will be grade-separated from both the CPR North Toronto Subdivision tracks and the CPR Wye track. The structures supporting the CPR North Toronto Subdivision will also accommodate up to four tracks allowing for two additional tracks in the future.

Figure 4 – Original Track Configuration

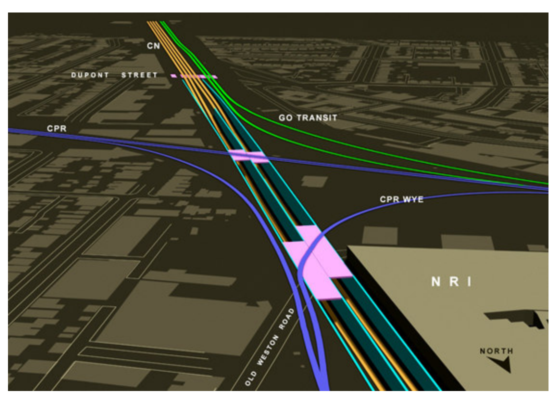

Figure 5 – Final Depressed Corridor

Due to the tight vertical geometry, and staging issues associated with providing one necessary operational CN track for the duration of the project, two separate corridors were detailed with a common centre wall. By dividing the corridor into two segments, the vertical clearances were achieved by incorporating maximum approach grades between the roadway constraints at the limits of the project, without requiring a track lift of any CPR tracks, hence greatly reducing the impact to CPR operations and associated trackwork.

3.0 Project Staging

The project staging evolved from the preliminary design and is a good example of how innovation and new ideas can be developed during the detailed design phase of such projects.

3.1 Preliminary Design

The preliminary design for the project considered the use of multiple track diversions in order to construct the structures at the railway crossings by conventional methods. This resulted in a significant amount of rail and signal work, including a main signal bridge relocation and several complex signal and cable bungalow relocations, as well as replacement of large transformers. The following is a list of the six track diversions identified in the staging set out in the original preliminary engineering report;

- Diversion of the Galt Subdivision south track to a new location.
- Diversion of the Galt Subdivision north track traffic and temporary suspension of service on the Galt Subdivision north track.
- Diversion of the CN Weston Subdivision onto a single track.
- Diversion of the CPR North Toronto Subdivision to the north.
- Diversion of the CPR North Toronto Subdivision to the south.
- Diversion of the CPR North Toronto Subdivision back to its original position.

The scope, scale, schedule and duration of the project revolved around these many track diversions, and the works associated with the ancillary (but very significant) signals and other relocations required to effect these track diversions. In addition, the project schedule took due account of the lengthy time (potentially) required for the various Railways to effect these diversions and signal relocations, and ultimately to reinstate the entire project.

3.2 Modifications to Preliminary Staging

Delcan reviewed the project with a view to seeing whether or not some of these track diversions could be minimized or eliminated, as they had such a significant effect on the scope, schedule and cost of the project.

As a result of our detailed review of the original preliminary engineering design for the staging of the project, we were able to re-work the entire project and develop a refined staging programme which eliminated all CPR and Galt track diversions. This was done by means of the incorporation in the design, of specialist sliding technology for the construction of the CPR bridges. This had a significant impact on the overall project, as it eliminated all but one of the track diversions (that being for CN) otherwise required.

Consideration was also given to eliminating the CN track diversion, and although it was found to be possible, we confirmed based on a detailed assessment that it was not truly economical to construct the project without the CN single track diversion, and thus it remained as the only track diversion for the project.

The revised staging plan and the proposed bridge sliding required review and acceptance from the Owner and the Railways before it could be deemed a successful innovation for this project. Considerable detail of the staging and sliding scheme was developed so that all the stakeholders could assess whether or not the proposal had merit. Ultimately, the Railways were very enthusiastic and found the advantages of the scheme to be clear and extensive. Delcan's experience in other large-scale heavy bridge slides was one key factor in the Railways and GO Transit accepting this unusual technique at the West Toronto Diamond site.

There was subsequently considerable discussion with the Railways regarding the technical aspects of the sliding, together with the sequence of possible track possessions which would be required to enable this project to proceed. It was found that the provision of equipment and services necessary to execute the sliding of such structures was a relatively limited portion of a project of this scale, and that the implementation of the sliding of the bridges at these two CPR/CN crossings should reduce the cost of the project by several million dollars and eliminate a number of major construction operations altogether, as well as having the potential to eliminate several months from the overall schedule, and certainly to eliminate a number of construction operations from the critical path of the schedule.

4.0 Components of Project

4.1 Utilities

It was determined that the extensive network of utilities should be routed around the limits of the walls for the depressed corridor. The key alternative, diverting the major watermain and significant sewer under the depressed corridor, was shown to be a high risk undertaking with no commensurate cost saving, A range of other alternatives was also investigated, including construction over the tracks, but these proved to not be feasible. By taking the utilities around the depressed corridor, the project schedule was improved by issuing an advanced early separate contract for the construction of the utilities, since this work was required to be completed prior to commencing with the works for the new depressed corridor.

4.2 Trackwork

The scope of the trackwork was significantly reduced by means of the introduction of the sliding of the CPR bridges, resulting in only CN trackworks being required, and with small impact to CPR required to remove and relocate the existing diamonds. The existing diamonds were incorporated into the CN diversion track alignment which reduced the schedule and cost, since the supply of new diamonds can take up to a year, and significant fabrication costs are involved.

4.3 Corridor Drainage

The depressed corridor will be drained utilizing a pumping station at the low point of the corridor. The station is incorporated into the permanent walls of the corridor and is designed to remove water from reservoirs, located underneath the CN tracks, by forcemain to a stormwater retention pond located adjacent to the corridor with controlled flow into the City of Toronto sewer network.

4.4 Retaining Walls

The retaining walls comprising the depressed corridor are approximately one kilometer in length, with a maximum excavation depth of 11 metres. A very significant added complication to the project was the relatively shallow ground water table which was found approximately five metres below existing grade.

The proposed wall system set out in the preliminary design report for this project was an interlocking steel pipe piling system. This type of piling was developed in Japan and was found to be virtually unknown in Ontario. It proved to have a number of advantages including the potential to virtually eliminate de-watering from this project, by means of cutting-off the ground water by means of the permanent steel pile walls. Extensive de-watering would otherwise be required and it was anticipated that such de-watering would be costly, subject to risks, claims and delays, and the subject of concerns from environmental perspectives as long-term dewatering could draw contaminants to the site.

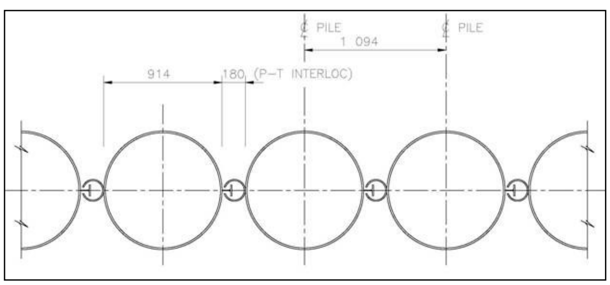

Figure 6 – Proposed Interlocking Pipe Wall

Figure 7 – Detail of Interlocking

After much review, it was decided that the interlocking steel pipe piling would indeed be utilized as a cut-off wall. This provided a predictable methodology of dealing with ground water during construction. The length of the corridor below the groundwater table is approximately 600m, and so this portion of the outside walls was extended into the underlying clay till, with end cut-off walls, to control the inflow of water into the excavation during construction. However, although this would be successful for construction, long-term flow could re-occur into the corridor and hence a base slab was developed to tie-in to the walls to prevent leakage and resist buoyancy forces as a result of the unbalanced head of water on either side of the walls. The base slab also assisted in providing propping to the bases of the walls, and in reducing impact to the nearby sensitive structures.

Due to the presence of the water table behind the walls, as well as the presence of frost-susceptible soils, insulation along the outside faces of the pipe pile walls was provided to avoid possible freezing of the soil during the winter months. Consideration was given to resisting the forces from the frost loading; however, it was found that the pressures developed under this scenario were far too high and it was not economical to resist them with the wall system.

4.5 CPR Bridges

The CPR bridges use the permanent walls of the depressed corridor, as foundation elements to resist the vertical railway loading. The pipe piles under the bridges were extended into the underlying till to provide the required end bearing capacity. Since the walls support the bridge superstructures, each superstructure was designed to perform as a permanent strut to the top of the wall. Horizontal loads from the soil pressures acting on the walls, and from the longitudinal railway loadings, are resisted by this interconnection of the two structural elements.

CPR Wye / Old Weston Road Bridge

Old Weston Road and the CPR Wye track converge just outside the limits of the depressed corridor. Due to the geometry of the roadway and the sweeping curve of the track, it was not feasible to separate the crossing into two structures, and a single slab bridge carrying both the road and the rail was developed. The slab structure also allows for two different alignments of the CPR Wye track, as required as a result of salvaging the existing diamonds for reuse on the CN diversion track.

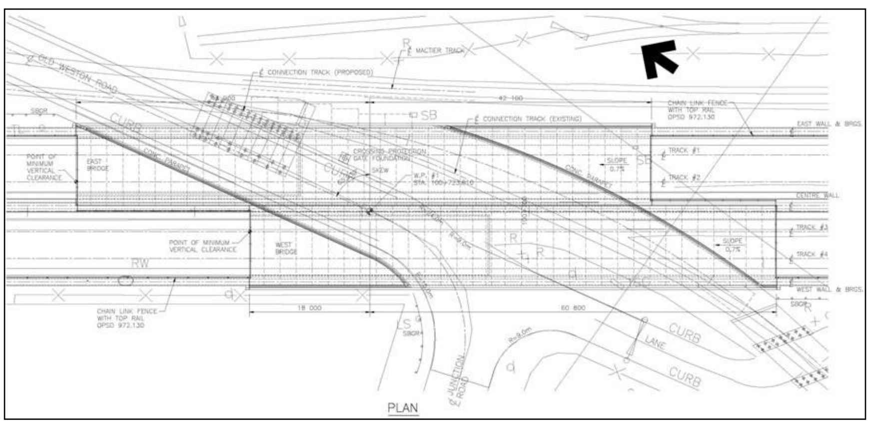

Figure 8 – Plan of CPR Wye / Old Weston Road Bridge

These bridges consist of pre-cast pre-stressed slab segments which are match cast and post-tensioned together. The thickness of the deck slab is 600 mm and 800 mm under the roadway and railway portion respectively, with a cast-in-place transition piece. The bridges for the east and west corridors are 86.0 and 78.8 m wide with a span of 11m.

North Toronto Subdivision Bridge

Slab bridges were also selected for the CPR North Toronto Subdivision bridges so that the existing track centres could be maintained and future tracks could be placed on minimum track centres to minimize the width of the rail corridor at the site. The North Toronto subdivision tracks also cross the depressed corridor on a 43 degree skew which becomes inconsequential with the slab type structures.

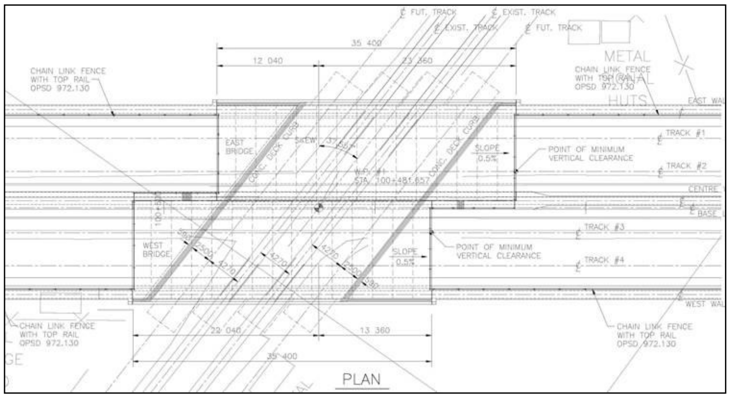

Figure 9 – Plan of North Toronto Subdivision Bridge

These bridges consist of 900 mm thick pre-cast pre-stressed slab segments which are also match cast and post-tensioned together. The bridges for both the east and west corridors are 35.4 m wide with a span of 11m.

5.0 Bridge Sliding

The technology for sliding major bridge structures is well-developed. In North America, sliding technology is typically applied in a more simplistic fashion than it is in Europe. Delcan has done several successful bridge slides in Canada, including the Dundas Street Bridge in Trenton, Ontario where Delcan designed and VSL executed the lateral slide of a three-span steel box girder bridge, and the Don Valley Parkway/CPR Underpass in Toronto where Delcan designed and Trafalgar House directed the longitudinal sliding of a tunnel under the same CPR tracks as those affected at the West Toronto Diamond site.

When bridge sliding was proposed for the railway structures, the appropriate technology for both the design and construction works was selected to enable safe, reliable and completely predictable performance. This is of particular importance with railway structures since the bridge slide must absolutely be successfully completed on schedule. If there is a problem, it only takes a few hours before the impact to the Railway, affects railway operations across the country.

The technology adopted for the bridge slides at the West Toronto Diamond site is the same group of technologies used by the British railroads, even on the high speed rail tracks carrying such trains as the Eurostar, and where their railway network is significantly more complicated than in North America. The use of similar slab structures for both crossings allowed for the same sliding technology to be used for both bridges.

Both the CPR Wye / Old Weston Road and CPR North Toronto Subdivision bridges are to be slid into place during short term possessions of the railway tracks. The bridges have been designed to be constructed adjacent to their final locations on slide paths which coincide with the centerlines of bearings.

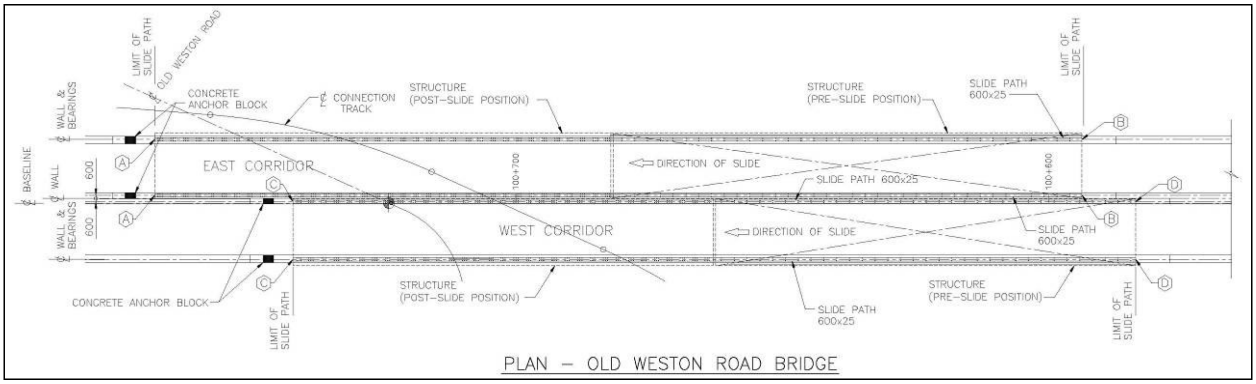

Figure 10 – Sliding arrangement for CPR Wye / Old Weston Road Bridge

Due to tight schedule requirements of the Railways, it was determined that the bridges would be slid on their permanent bearings and secured in place after the slides. Since the permanent bearings are to be used for the sliding, it was important to establish how the sliding mechanisms would be built into the bearing assemblies and how they interacted with the bearing slide path. Elastomeric bearings were detailed as the vertical load-supporting element and were placed within steel assemblies which could resist the large lateral loads due to the bridges providing lateral support to the tops of the walls, in addition to being able to incorporate the specific sliding surfaces required in the overall bearing assemblies.

The sliding system for this project incorporates large high-speed tandem hydraulic jacks controlled by computerized systems which can ensure movements and loads are properly monitored for accurate positioning and uniform movement of the structure at all times during the slide. The tandem jack arrangement allows the slide to progress at a steady rate without disruption, as one jack is always engaged. The anticipated rate of advancement for bridges utilizing this technology is 20m/hour, which translates to a four hour slide for the 80m long Old Weston Road structure and a two hour slide for the North Toronto Subdivision bridge.

The sliding aspect of the project was verified by VSL International, a specialist contractor, in both the design and the construction works associated with the sliding of such structures so that the design and construction activities were fully integrated and so that risk to the Owner and to the Railways was minimized by ensuring that the designs are completely identified in terms of a specific sliding system and methodology, and that the sliding contractor involved in the design, in fact, carries out the actual sliding as well.

6.0 Silent Piling

As noted previously, the original preliminary engineering proposed that the very extensive retaining walls required on this project be constructed using interlocking steel pipe piling. Noise from piling operations was a main concern for this project due to the estimated duration of the wall construction (up to one year) and the residential properties in close proximity to the site, which led in part to the introduction of silent piling for this project.

The silent piling method was presented in the preliminary engineering report as pressed-in or hydraulic crush piling, developed by the Giken Corporation in Japan. This methodology involves a linear type of wall construction. Piles are pressed into the ground by reacting against several previously-installed piles anchored by skin friction developed by the piles and the soil. The method of installation exhibits very little if any vibration, which should prove to be very advantageous at this site, particularly due to the noise limitations and nearby sensitive structures.

Figure 11 – Giken Crush Piler in Japan

During the detailed design, Delcan undertook several site visits to observe the Giken silent piling operations on other sites in the USA and in Japan, and was able to compile a sound understanding of the pros and cons of silent piling, and the limitations of these methodologies. Delcan also initiated detailed discussions with local foundation contractors to develop the piling design and specifications to best suit the soil conditions at the site. Since the wall of the depressed corridor makes up the majority of the cost of the project, refinements could yield significant returns by reducing the overall project cost. In addition the risks of the use of a novel piling methods could have cost implications. Hence a pile installation test programme was conducted on the site.

A full scale test installation of 12 piles was completed on the site during the detailed design phase, incorporating various construction methodologies in order to get a better appreciation of the vibration impacts, speed of production and limitations of the methods. The methods used for the test piling included: diesel hammer, conventional vibratory driver, and variable moment vibratory driver. This test was intended to include silent piling; however due to equipment demands elsewhere, Giken could not provide equipment at the time of the demonstration.

Figure 12 – Pile Demonstration at Project Site

Nevertheless, the pile demonstration proved to be very helpful, with positive results indicating that advancing the piles though the soils at this site was not as difficult as expected based on the borehole information, and the use of silent piling may not be required for significant lengths of the depressed corridor due to the favourable vibration levels which were monitored for the other methods. As a result, it is more probable that vibratory driver technology will be used to install the bulk of the interlocking steel tube piling on this project, and silent piling is specified for the most critical parts of the project, adjacent to existing buildings and other facilities.

7.0 Conclusion

The sliding works proposed for this project involve substantial high-capacity high-speed specialist hydraulic computer-controlled systems works. This specific equipment and the process of sliding large structures with it, have been but rarely if ever used in North America in the context of rail bridges. It can fairly be said that the West Toronto Diamond project, as a result of the implementation of these works, is a true leading-edge project in terms of the technology for the construction of major railway grade separation projects in North America.

The requirement for minimizing disruption of existing traffic is paramount with the Railways, as any disruption impacts their business and has direct costs to the Railways. Similar innovative ideas need to be considered to assist in reducing the impacts which construction has on traffic, for other future railway and roadway projects. This perhaps will become more prevalent with the presence of toll highways such as the Highway 407 in Ontario, where the impact of traffic disruption may cause loss of customers and revenue. However, economic reasons should not dominate the decision of when to apply innovative ideas, particularly on public highway projects, where the impacts of traffic disruption is somewhat more difficult to calculate, but definitely has a negative impact on society and the environment.