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Island Park Drive Rapid Bridge Replacement

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ABSTRACT

Ontario's Ministry of Transportation (MTO) used a rapid replacement technique for the first time in Canada to remove and replace two bridges in 15 hours on the busiest thoroughfare of the Nation's Capital. On August 11, 2007, the twin structures, 4 lanes and weighing 650 tonnes each, were removed by self propelled modular transporters and replaced with two new structures that were constructed in a nearby staging area. The removal and replacement of the bridges required a complete closure of Highway 417 (Ottawa Queensway).

The ultimate context sensitive design converted the bridges to semi-integral abutments, used adjustable bridge bearings and increased worker safety by allowing construction to be performed in a safe environment without exposure to traffic. The design included a full risk assessment and required a coordinated team effort. Experts from the ministry, City of Ottawa, the contractor and representatives of the heavy lift technology and transporters worked together to ensure project success with minimal impact on the environment.

What normally would have required two full construction seasons with traditional staging, traffic shifts and delays was completed overnight saving an estimated $2.4M, significantly reducing the length of traffic delays, societal costs and resulting environmental impacts. Although this project did not specifically track vehicle emission levels, theoretical estimates indicate that utilizing rapid bridge replacement technology can reduce hydrocarbon, CO and NO emissions compared to a conventional construction approach.

Since the successful completion of the Island Park Bridge replacement, the ministry has awarded the next pair of twin structure removal and replacements at Clyde Avenue and will continue with the removal and replacement of three more twin bridges on Highway 417.

INTRODUCTION

Highway 417 is a major urban freeway that serves as the only east-west highway corridor through the City of Ottawa. This part of the highway was constructed between 1959 and 1967 and carries more than 150,000 vehicles each day (150,000 AADT). Twelve bridges (EB and WB) located at 6 sites were nearing the end of their design life and required rehabilitation or replacement. A general view of the highway and the locations of the bridges are shown in Figure 1.

The project limits are along Highway 417 (known locally as the Ottawa Queensway), from Maitland Avenue to Island Park Drive, where widening of the freeway is taking place to 4 lanes in each direction. The twelve bridges (six sites) are identified with the red dots in Figure 1 and include Clyde Avenue, Carling Avenue EB, Kirkwood Avenue, Carling Avenue WB, Merivale Road and Island Park Drive. Contract 1, which occurred in 2007, involved the rapid replacement of the two superstructures located at Island Park Drive, at the east limits of the project. Unlike the other five sites, widening was not necessary at Island Park Drive as these structures already comprised 4 lanes in each direction. Contract 2 involves rehabilitation and widening of the Clyde Avenue structures to occur in 2008. Contract 3, comprising the remaining 4 sites, will take place in future years. All but Merivale Road include the rapid replacement of superstructures. Since the structures at Merivale Road are rigid frames, superstructure replacement using rapid replacement technology is not possible. A conventional approach to rehabilitation and widening will take place at this site.

The ministry, in the initial planning process, investigated the option of rehabilitating or replacing these bridges using a conventional approach of staged construction. This staged construction would have involved closing traffic lanes to work on the bridges one section at a time over two construction seasons (April to November each year). The ministry realized that rehabilitation or replacement of these bridges using a conventional approach would impose considerable traffic congestion, traffic delays, significant environmental impacts associated with traffic congestion and the potential of increased accidents. The challenge faced by the ministry was to undertake this work with minimal disruption to the daily life of road users and to keep the environmental impacts to a minimum.

The ministry investigated various alternatives and decided to adopt rapid replacement technology that has been used successfully in Europe and the USA. This technology is new to Canada and had never been tried on any of the provincial highways in Ontario. The key to rapid replacement technology is the use of special equipment known as Self Propelled Modular Transporters (SPMT). SPMTs can lift very heavy loads and are able to move and place them in predetermined locations accurately and safely. The approach used for Highway 417 was to build the new bridge superstructures in a location close to the bridge site, lift out the old bridges using the SPMTs and move them to a storage area for future demolition, transporting the new bridge superstructures from the staging area and placing them in position. This paper describes the successful completion of the rapid replacement of the superstructures at Island Park Drive in 2007.

RISK ASSESSMENT AND RISK MITIGATION PLANS

A comprehensive risk analysis was undertaken to identify and to mitigate all project risks and was conducted at 30% design completion. The implementation of a detailed risk management plan was viewed as key to ensuring that the bridge replacement could be achieved within one overnight closure.

The risk assessment was conducted in a workshop environment and regrouped members of the project team, risk team and subject matter experts (e.g. contractors, engineers, and subject matter experts in rapid lift replacement, cost estimating and scheduling). Figure 2 summarizes the process followed for the Risk Assessment Workshop.

A risk register identifying all project risks (including probability of occurrence) to the overall project cost and schedule was developed and identified thirty-four risks/opportunities.

The risk management analysis indicated that there was a 90% probability that the rapid lift operation could be completed in a 15 hour window. A similar probabilistic approach was determined for the overall project cost based on the base cost estimate information utilized at the workshop.

Throughout the detail design period, the risk register was updated on a regular basis with response actions developed against all 34 risks/opportunities.

To address identified risks associated with the full section closure, significant incentives and disincentives were written into the contract. If the highway was open fully to traffic early, the contractor could be rewarded with a payment of up to $220,000. Conversely, if the highway remained partly or completely closed to traffic past the pre-determined time, the contractor could face financial penalties of up to $585,000. As it turned out, the highway was opened to traffic on time and no incentives or disincentives were applied to this portion of the project.

BRIDGE DETAILS AND WORK DESCRIPTIONS

The Island Park Drive Bridges are twin structures that were built in 1961 and span a local road underneath. The bridges have a single span, slab-on-steel girder bridge superstructure and have a very high skew angle of 50 degrees. The span length is 25 m and the width of each of the structures is approximately 18 m. The abutment is a conventional concrete wall on spread footings with a height of approximately 6.0 m above ground. Details of the bridges and their condition prior to removal are illustrated in Figures 3, 4, 5, 6 and 7. It was decided that each superstructure would be replaced with a new slab-on-steel girder type superstructure and the abutment walls would be repaired and re-faced.

The scope of work for this bridge replacement project included:

a) replacing the superstructures using rapid lift technology with full closure of Highway 417 for 15 hours.
b) construction of the new superstructures and demolition of the old superstructures within the staging area.
c) converting the new superstructures to semi-integral abutment type and approach slab construction with rapid set concrete.
d) repairing abutments with installation of new sacrificial cathodic protection and re-facing.
e) replacing the existing noise barrier, illumination and advanced traffic management systems.
f) rehabilitation of Island Park Drive, reinstatement of the construction area and related landscaping work.

The main bridge replacement operation involved four major phases:

Phase 1: construction of new superstructures and rehabilitation of abutment walls.
Phase 2: pre-rapid lift operations completed over three preceding weekends.
Phase 3: rapid lift operation completed on August 12, 2007 in 15 hours (Figure 8).
Phase 4: post-rapid lift operations carried out in the proceeding two weekends to complete all of the major work.

The two new superstructures were designed and built on temporary supports erected at the construction site at a height similar to their final positions to reduce the time required to raise or lower the bridges to suit the final elevations. The girder bearing locations and the girder spacing were kept the same as the old structure and new bearing details were developed to be easily adjustable in order to minimize any possible delays.

The pre-rapid lift operations involved closing selected traffic lanes on the weekends, removing the existing approach slabs, removing granular fill behind the ballast wall, attaching the ballast wall to the existing superstructure, saw cutting the ballast wall for removal with the superstructure as a total entity and back filling with granular and temporary pavement placement for the highway to be fully operational. This operation was repeated across the whole width of the structure in three weekends with short term lane closures to prepare the structure for the final removal and replacement operations.

The rapid replacement operations involved completely closing a 3 kilometre portion of the highway, removing the asphalt and granular back fill behind the ballast wall, raising and moving the existing superstructures to the staging area, transporting/placing/levelling the new superstructure in position, backfilling/paving/placing of temporary traffic barriers and opening the bridge to regular traffic.

Since this highway is within the core of the City of Ottawa and within the purview of the National Capital Commission, context sensitive design considerations were applied to the Island Park Bridge replacement project. The appearance of the new bridge was enhanced by using coloured concrete sealers on all walls and a new noise barrier was embedded with patterns. Landscaping and other improvements were also completed along Island Park Drive within the proximity of the bridge.

TRAFFIC OPERATIONS AND ENVIRONMENTAL IMPACTS

A conventional bridge replacement project would have necessitated a reduction of live traffic from 8-lanes to 4-lanes during construction. It is important to note that the ministry did not empirically calculate traffic or environmental impacts of either a conventionally installed bridge or a bridge installed using rapid replacement technology. The analysis in this section is based on best practices for traffic management and staging focussing on queue length and queue dissipation for the demand volume for the peak hour and assumptions include:

a) AADT of 150,000
b) directional split is 50/50
c) peak hour factor (PHF) is 10%
d) heavy vehicle (HV) percentage is also 10%
e) peak hour volume was assumed to be 7500 vehicles per direction

The maximum queue resulting from reducing the number of lanes per direction from 4 to 2 would be 6.6km, which in turn would affect 880 vehicles for the peak period and would take two hours to clear the queue from this peak hour volume.

The theoretical amounts of Hydro Carbon (**HC**), Carbon Monoxide (**CO**) and Nitrogen Monoxide (**NO**) that passenger and commercial vehicles would emit into the atmosphere as a result of queuing and queue dissipation due to lane reductions in the peak hour are shown in Table 1.

Table 1 – Hourly Emissions Generated During Peak Volume Periods for Conventionally Built/Installed Island Park Drive Bridges (grams/hour)

HC		CO		NO	
Autos	**Trucks**	**Autos**	**Trucks**	**Autos**	**Trucks**
15,028	4,811	228,275	52,694	8,375	9,814

This data can be used as base information to estimate the total vehicular emissions generated for this project using further assumptions:

a) 2 peak periods per workday (am and pm);
b) 2 hours per peak period to clear the queue;
c) 5 workdays per week;
d) 35 weeks per construction season (April 1 – November 30);
e) 2 construction seasons.

The estimated total vehicle emissions generated as a result of conventional bridge methodology for the replacement of the Island Park Drive bridges is illustrated in Table 2.

There were some minor traffic impacts as a result of 3 weekend pre- and 2 weekend post-rapid lift operations as well as the 15-hour full section closure (the full lane closure caused no traffic delays or queues on the night of the rapid lift and the resulting additional emissions for that event were assumed to be zero). Using these traffic impacts as a comparison, it was possible to calculate the emissions generated as a result of using rapid bridge replacement technology (see Table 2).

Table 2 – Comparison of Total Emissions Generated for Island Park Drive Bridge Replacement Project (Conventional versus Rapid Replacement Technology)

Using Conventional Methodology		
HC	**CO**	**NO**
27,775 kg	393,356 kg	25,465 kg
Using Rapid Bridge Replacement Technology		
HC	**CO**	**NO**
795 kg	11,240 kg	730 kg

Table 2 illustrates that vehicle emissions were reduced 97% by using rapid bridge replacement technology compared to a traditional replacement process. This theoretical estimate supports information and conclusions from other published sources.

According to Environment Canada, every litre of gasoline used in a vehicle produces 2.4kg of carbon dioxide (CO_2) and every 10 minutes of idling uses 0.10-0.40 litres of fuel [1]. Based on this relationship, every 10 minutes of idling produces 0.24-0.96 kg of carbon dioxide per vehicle.

It is generally accepted that as traffic congestion increases, fuel consumption and vehicle emissions also increase. Many environmentally-based information strategies promote the concept of steady-flow or free-flow traffic as one method to reduce vehicle emissions and fuel consumption. A study undertaken along highways in Southern California has demonstrated that strategies aimed at reducing congestion and promoting higher average traffic speeds through construction zones can lower CO_2 emissions by 7-12% and techniques that reduce the number of start/stop events can lower emissions by another 7-12% [2].

To further support this concept, a traffic study of vehicle emissions in Anna Salai, India showed that hydrocarbon, CO and NO emissions were reduced by 45-47%, 30-38%, and 6-18%, respectively, when traffic was less congested with fewer start/stop events [3].

These results clearly illustrate the environmental benefits of using rapid replacement technology to replace bridges on highways like Highway 417 which have large traffic volumes.

CONCLUSIONS

The Island Park Bridge Rapid Replacement project was successful at many levels. From an engineering perspective, a new standard has been set across the country for bridge replacements on provincial highways using this innovative process. From a traffic operations perspective, congestion and delay related impacts were reduced from years to days. It was demonstrated that this technology can reduce the environmental impacts of highway construction activities by reducing hydrocarbon, carbon monoxide and nitrogen monoxide emissions by as much as 97% compared to a traditional bridge replacement method. The Ottawa Citizen's editorial view summed it by saying – "Building Bridges to the Public; Construction projects usually make city-dwellers feel cynical, frustrated, isolated, angry, and ripped off. The Island Park Drive bridge project did exactly the opposite".

References

1. e-Document. *Lowering Canada's Vehicle Emissions*. Issue 54, May 13, 2005. http://www.ec.gc.ca/EnvironZine/english/issues/54/freature2_e.cfm

2. Barth, Matthew and Kanok Boriboonsomsin (2008). *Real-World CO_2 Impacts of Traffic Congestion*. 87th Annual Meeting of the Transportation Research Board.

3. Sivanandan, R., S. P. Anusha, and S. K. SenthilRaj. *Evaluation of Vehicular Emissions under Lane Restricted Heterogeneous Traffic Flow*. 87th Annual Meeting of the Transportation Research Board.

FIGURES AND PHOTOS

Figure 1 – Project Limits

The project limits extend from 0.5km west of Maitland Avenue to 0.2 km east of Island Park Drive in Ottawa.

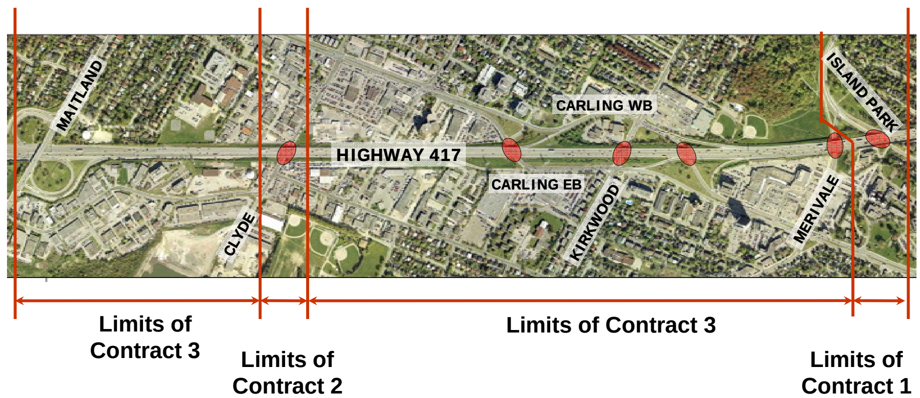

Figure 2 – Risk Assessment Workshop

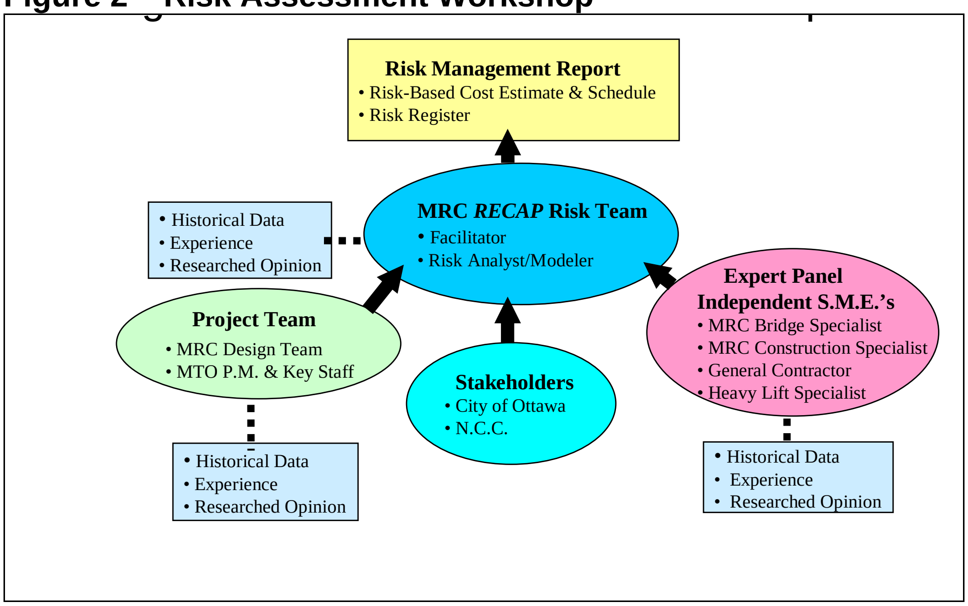

Figure 3 – Plan View of Bridge

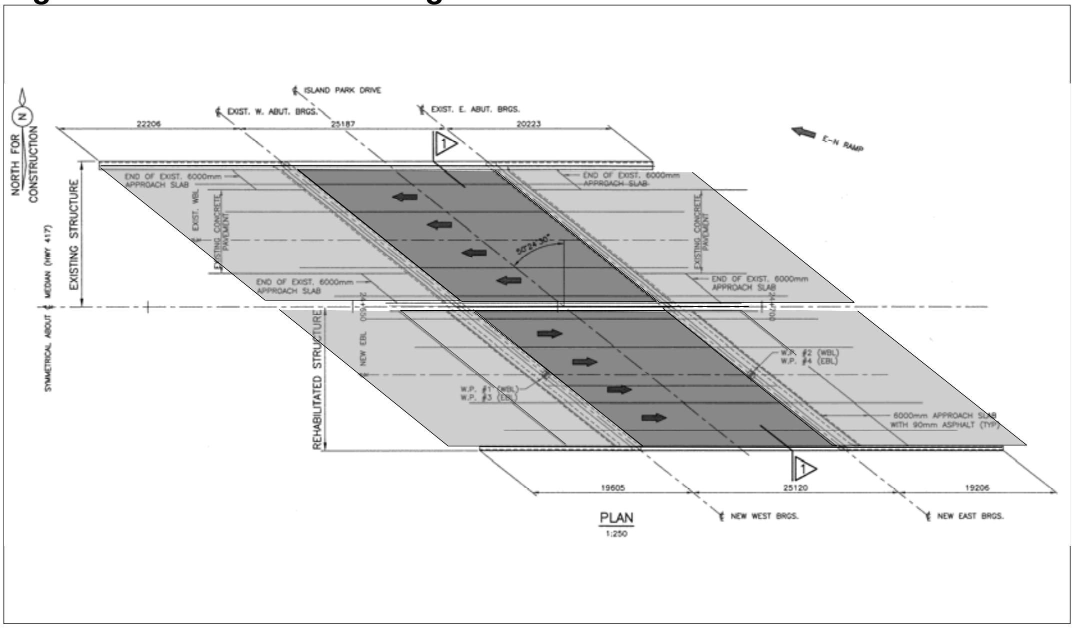

Figure 4 – Bridge Cross Section

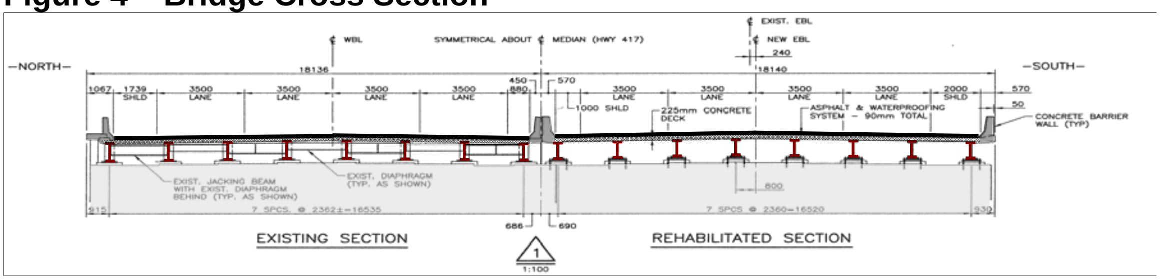

Figure 5 – South Elevation

Figure 6 – Soffit Condition

Figure 7 – Semi-Integral Details Used for New Superstructures

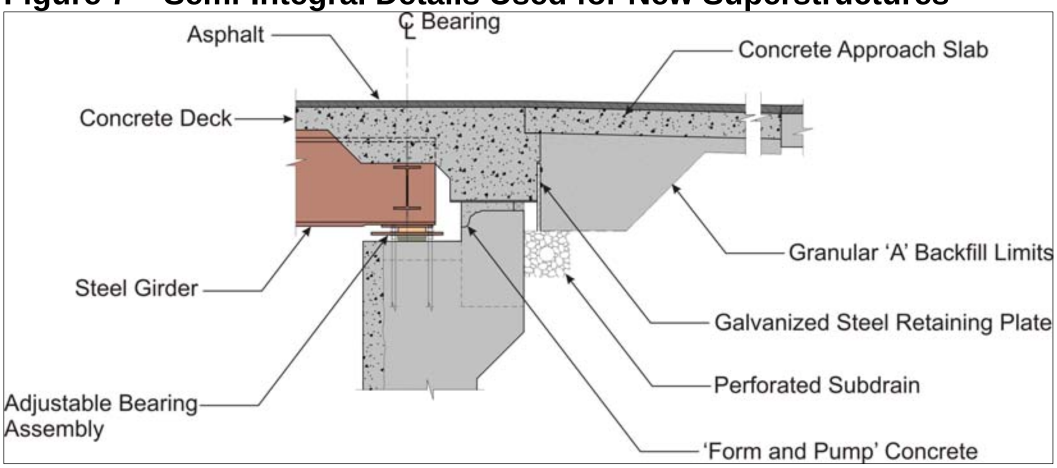

Figure 8 – Bridge Span Being Transported by SPMT