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Continuous Bridge Slides Laterally into Final Position

Pont à poutres continues glissé latéralement dans sa position définitive

Querverschub einer Durchlaufträgerbrücke

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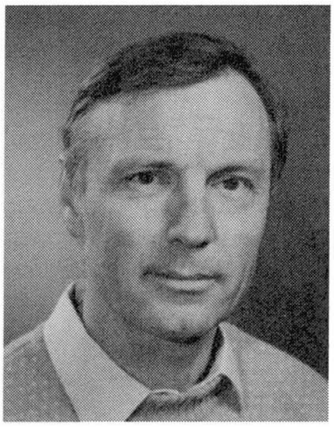

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SUMMARY

The Dundas Street Bridge in Trenton, ON, Canada was constructed to replace an aging multi-span bridge. The new bridge is a three-span continuous bridge which, following its completion, was moved laterally into its final position by a computer-controlled hydraulic jacking system. The methodology enabled replacement of the old bridge by a new bridge on the same horizontal alignment with only an eight-day interruption to traffic, and with minimal interference with adjacent property, buildings and underground structures.

RESUME

Le pont de la rue Dundas à Trenton, ON, Canada a été construit afin de remplacer un vieux pont à travées multiples. Le nouveau pont est à trois travées continues. Après sa construction, le pont a été déplacé latéralement dans sa position définitive, par un système de vérins hydrauliques assisté par ordinateur. Cette méthode a ainsi permis le remplacement du vieux pont par un nouveau mis en place dans le même alignement horizontal, avec un arrêt de la circulation de huit jours seulement. En outre cette méthode a permis un minimum d'interférences sur les propriétés, édifices et structures souterraines avoisinants.

ZUSAMMENFASSUNG

Die neue Dundas-Strassenbrücke in Trenton, ON, Kanada, ersetzt eine alte Brücke. Die neue Brücke, eine durchlaufende 3-Feld-Konstruktion, wurde nach ihrer Fertigstellung mit Hilfe eines computergesteuerten hydraulischen Verschubsystems in ihre definitive Position verschoben. Diese Methode erlaubte es, die Brücke nach nur acht Tagen Verkehrsunterbruch an ihrer endgültigen Lage betriebsbereit zu haben. Dies mit minimalen Behinderungen der angrenzenden Anlagen, Gebäude und unterirdischen Leitungen.

1. INTRODUCTION

The replacement of the Dundas Street Bridge in the City of Trenton has introduced to North America a specialist technology for the lateral sliding of large continuous bridges. This unique bridge engineering project was designed by Delcan Corporation of Toronto to meet a variety of challenges posed by the requirements of the owners of the project, the City of Trenton. It provides an example of the influence of specialist construction techniques on the configuration and design of steel bridges.

The old Dundas Street Bridge was a 70-year-old swing bridge which included a swing span and three through-truss approach spans. The bridge was replaced by a high level bridge which eliminated the maintenance and operating costs associated with the aging swing bridge and the interference with vehicular traffic posed by the frequent opening of the swing bridge.

The construction scheme enabled the new bridge to be constructed on exactly the same alignment as the old bridge, which is the ideal alignment at this site, with only a one-week interruption to vehicular traffic. Without the special techniques which were incorporated in the design, the construction of a conventional new bridge on the alignment of the old bridge would have involved the closure of the crossing for up to 18 months.

This significant benefit was built into the design and the construction by means of a structural and hydraulic system which enabled the bridge to slide from its initial position adjacent to the existing bridge into its final position coincident with the alignment of the old bridge. This was accomplished by means of a series of slide paths and launching carriages and a synchronous computer-controlled hydraulic system which powered the bridge during the lateral sliding operation. This in turn enabled construction of the new bridge on its ideal alignment with minimal interference with vehicular traffic and with minimal interference with adjacent properties, buildings and underground structures. It was for these reasons that this was the most cost-effective technique for construction of the required new bridge at this site.

The construction of the bridge up to the point of sliding is described in detail in Reference [1].

2. NEW BRIDGE

The new bridge is a three-span structural steel box girder bridge. The main span is 74 m and the two side spans are 54 m for a total length of 182 m. It was designed as a variable-depth girder bridge with a depth of 3.2 m at the piers and 1.7 m at the mid-span. This enabled construction of the new bridge with the minimum approach grades compatible with the requirement that the bridge provide clearance for boat traffic on the Trent River.

The bridge includes two lanes of traffic and two sidewalks and has a design weight of 2950 tonnes. It is supported on conventional pot bearings which were modified to suit the requirements for the sliding of the bridge. The bridge in its final configuration is supported on conventional reinforced concrete piers and abutments founded on bedrock.

The bridge is shown in elevation in Figure 1.

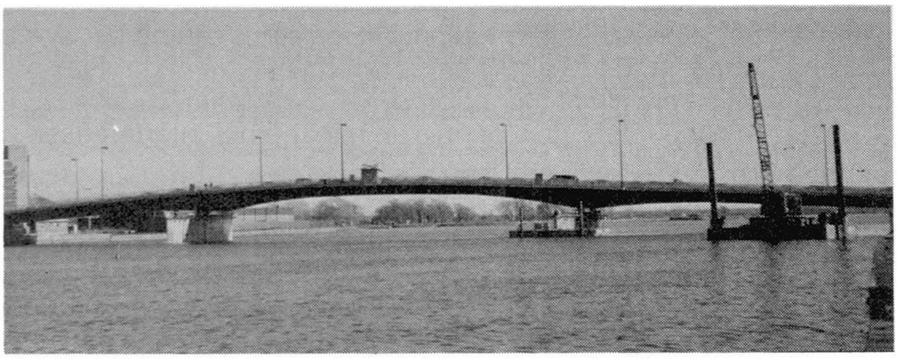

Figure 1 - Dundas Street Bridge immediately prior to slide.
Central Control Room at Midspan

3. CONSTRUCTION SEQUENCE

The construction sequence included the following steps:

- Reversal of the direction of the swing of the old swing bridge in order to minimize the impact of the swing bridge rotation on new bridge construction during the navigation season.
- Construction of the major portion of the new bridge immediately adjacent to the swing bridge but without interfering with the rotation of the swing bridge.
- Completion of the erection of the structural steel adjacent to the swing span after closure of the navigation season followed by completion of the superstructure of the new bridge. Thus the new bridge is complete with deck, waterproofing and asphalt, barriers, railings and lighting and is ready to enter service, but is not yet in its final location.
- Transfer of traffic from the swing bridge to the new bridge on a temporary alignment which, though deficient for long-term service, is adequate to provide connection to the existing Dundas Street Bridge for a relatively short period of time in temporary service.
- Demolition and removal of the swing bridge including its substructures.
- Extension of the piers and abutments of the new bridge into the area previously occupied by the swing bridge to accommodate the new bridge in its permanent location.
- Closing of the entire crossing to vehicular traffic for a period of approximately one week.
- Sliding of the new complete bridge from its original into its final position coincident with the alignment of the old swing bridge. This involves the sliding of the complete new bridge a distance of 10 m.
- Opening of the crossing to traffic.

4. INFLUENCE OF CONSTRUCTION TECHNIQUE

The scheme described above, which included the sliding of the complete bridge, was considered by the City of Trenton to provide the minimum cost-benefit ratio in comparison with a number of other schemes. This was essentially for the following reasons:

- Costly property acquisition was minimized.
- The alignment is as near to the ideal as possible in terms of traffic operations.
- Interference with navigation on the river was eliminated.
- The closure of the crossing to vehicular traffic was minimized.

The introduction of the requirement that the new bridge be moved laterally after its completion had a significant effect on the construction techniques utilized during this project. In the first place it was considered desirable that the new bridge be as light as possible and this, in conjunction with other geometrical constraints at the site, dictated that the bridge comprise structural steel box girders. It was necessary, too, to include in the design and contract documents a detailed design and description of the sliding mechanism and the computerized control system for jacking operations. The contract documents included tolerances related to the requirement that the bridge must slide, and included the design and description of mechanisms for guiding the bridge during the slide and for modifying the fixity of the main bridge bearings so that the bridge was at all times stable in terms of translation, yet was able to rotate at all bearing locations as required.

So far as is known, this is the first major multi-span continuous bridge to be moved laterally in this fashion in North America, although there are a few examples of similar bridge slides in Europe. Accordingly it was deemed appropriate that a special Risk Management feature be built into the contract documents whereby it was a requirement of the contract that the General Contractor retain the services of a specialist subcontractor to carry out the bridge slide itself. It was incumbent upon the specialist subcontractor to check the design of the sliding structure, and to supply and operate the jacks and the computerized control system necessary to move the structure. It was also a requirement that the specialist subcontractor be experienced in similar bridge slides.

The General Contractor, Bot Construction Limited of Oakville, Ontario, retained the services of VSL International Ltd., of Lyssach, Switzerland as the specialist subcontractor and VSL International Ltd. executed this specialist work. This was considered a key factor in reducing the risk associated with this project.

5. DESCRIPTION OF SLIDE MECHANISM

The sliding mechanism described in the contract documents comprised the following elements:

- Four heavy structural steel track beams set on each of the two piers and two abutments and carefully aligned.
- Teflon/steel sliding elements fixed to each of the track beams.
- Heavy structural steel launching carriages fitted with stainless steel sliding surfaces which sit on the Teflon/steel sliding elements and which are set out in pairs on each of the abutments and piers, and support the bridge.
- Steel wheel guides attached to the launching carriages on the fixed pier only. These guides prevent movement of the bridge in the longitudinal direction by means of bearing against the track beam on the fixed pier during the slide.
- Conventional pot bearings fixed to the launching carriages. The bearings are equipped with structural steel plates bolted to the bridge in order to restrain translation of the bridge relative to the bearings during the slide, when the bridge would instead translate on the stainless steel/Teflon surfaces between the launching carriages and the track beams.
- Hydraulic jacks, pumps and electronic equipment. The jacks supplied each produced 70 tonnes at safe working capacity. Two such jacks were installed at each pier and one such jack at each abutment in order to pull the bridge. The jacks were doubled-acting hydraulic jacks which pulled high-strength strands.
- A similar set of six jacks was supplied in order to pull the bridge back in the opposite direction if necessary.
- The high strength strands were supplied in groups of seven at the piers and four at the abutments.
- The jacking system was controlled by a synchronous computerized control system which conformed to specifications prepared by Delcan and which was supplied and operated by VSL International Ltd.

The bridge, mounted on the launching carriages and equipped with the jacking system, is shown in Figure 2. Details of the launching carriage and bearing assembly are shown in Figure 3.

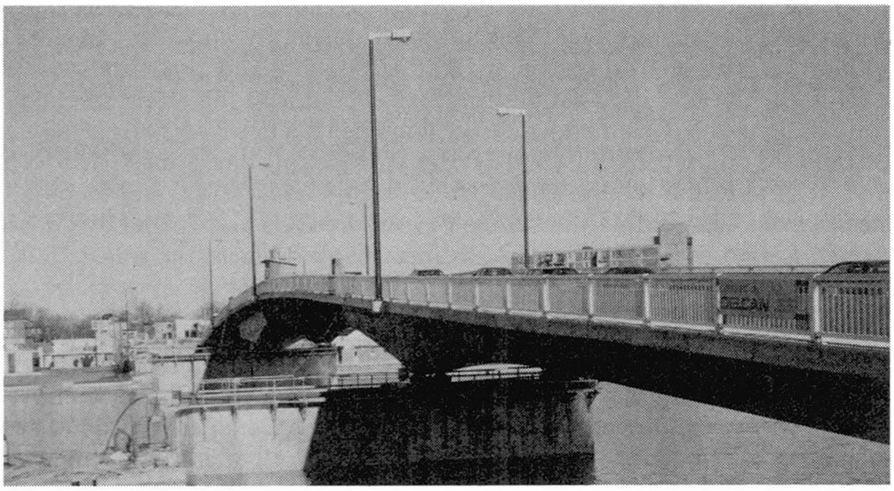

Figure 2 - Bridge mounted on launching carriages and equipped with jacking system.

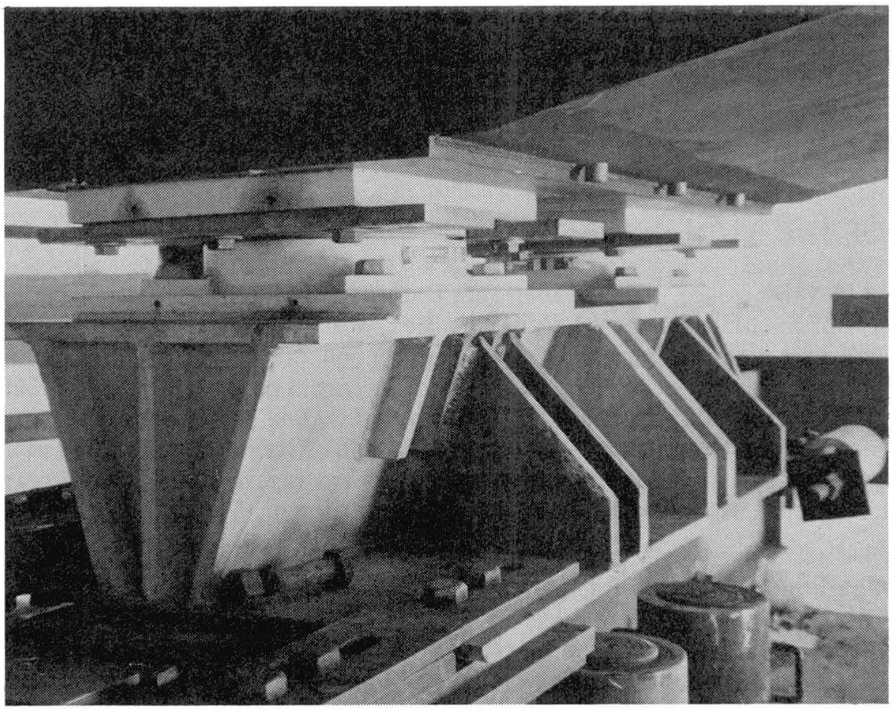

Figure 3 Details of launching carriage and bearing assembly showing bearings; bolted steel plates to inhibit translation of bridge relative to bearings; welded launching carriage; and (bottom left) steel-reinforced Teflon-coated neoprene pad projecting from beneath the launching carriage.

6. IMPLEMENTATION OF RISK MANAGEMENT PROCEDURES

The contract documents were set out to include detailed designs for all of the above-noted elements of the sliding structure and control system. At the same time it was recognized that the specialist subcontractor who would operate the bridge during the slide was not known at the time that the designs were prepared. Therefore, the contract documents were made flexible enough to allow the specialist subcontractor to review and, if necessary, suggest modifications to any element of the design of the sliding mechanism prior to the execution of the slide.

In the event, this review was carried out by VSL International Ltd. Their review suggested that the Teflon/steel sliding elements located on the track beams be replaced by a 13-mm Teflon-coated, steel-reinforced neoprene pad system. This system accorded with their previous experience with similar bridge slides and it was therefore accepted that this modification be made. By a similar rationale, the steel guide wheels noted above were replaced by aluminum-bronze blocks in order to guide the bridge in the longitudinal direction. In this way the key requirements for the bridge slide as set out in the contract documents were respected but, at the same time, the specialist subcontractor was able to have a maximum degree of input into the final design of the bridge.

7. HYDRAULIC SYSTEM AND COMPUTERIZED CONTROL SYSTEM

The six double-acting jacks which provided the main motive force during the slide were connected to four hydraulic high pressure pumps, one located at each substructure. The sliding of the bridge was controlled from a central control room, located on the bridge, which contained television monitors, pressure gauges, digital readout devices and the centralized computer control.

Displacement sensors installed at each substructure provided data to the actual computerized travel control. The data was visually displayed in 2 mm increments. Television cameras mounted on the bridge at each substructure sent an image of a fixed scale to the control room, thereby providing visual backup to information received from the displacement sensors, as well as the actual sliding distance.

The pumps were set to shut down if a maximum pressure (which was preselected) was reached. This ensured that if the pressure built up at one substructure, for example, all pumps would shut down and the structure stop moving. In this manner it was possible to predict that the structure would not move differentially more than about 5 mm across the length of the bridge, subject to adjustments which could be input by the operator. This ensured in turn that the bridge was not damaged during the slide.

8. SLIDING OF THE BRIDGE

In order to start up the bridge, VSL International Ltd. installed both the pulling jacks described above and in addition four pushing jacks. The pushing jacks were located one on each substructure. These pushing jacks had a stroke of 20 mm and they pushed in concert with the pulling jacks in order to start the bridge off. In this way, the very first step, when the initial break-out friction had to be overcome, was smoothed. The entire jacking operation was operated by one person from the central control room. The jacking system was programmed to stop at every 20 mm of travel. Once sliding at all 4 substructures had automatically completed a 20 mm step, the jacks were reactivated by the operator for the next increment of movement. In this way the position and condition of the bridge was checked every 20 mm.

When the bridge first began to slide, it moved in a slightly unexpected fashion with the east abutment carriages moving forward a few millimetres under no load. It is believed that in-built stresses, attributed to one-sided exposure to the sun, were released. As a result, the displacement sensors were adjusted and the bridge immediately returned to the appropriate position and moved exactly as planned. For a significant portion of the slide the jacking was carried out without pressure acting at the east abutment. In the latter stages of the slide jacking was carried out with virtually no pressure at the west abutment.

The maximum variation of displacement of the superstructure among the pier and abutment locations was generally between 1 mm and 2 mm, varying up to 5 mm from time to time.

A typical incremental rate of speed was 0.80 m in 15 minutes, or 3.2 m per hour. The average rate of speed was 2.5 m per hour and the entire slide was accomplished in 3 hours, 57 minutes.

Pressures exerted by the longitudinal guides appeared to be very low as there was very little sheen of bronze left on the track beam by the guide.

Following the completion of the slide, the bridge was restored to a conventional configuration by means of the fixing of the launching carriages to the track beam and the freeing of the bearings relative to the launching carriages. The launching carriages and the track beams were then encased in reinforced concrete. The bridge in its final configuration thus is indistinguishable from a normal bridge.

9. SUMMARY

The construction of the Dundas Street Bridge included a number of unusual elements which necessitated the integration of the design and construction and ensured that the construction techniques had a significant effect on the design of the bridge. The resulting integrated effort by the designers and the contractors, including the specialist subcontractor, resulted in the construction of a bridge which met the requirements of the owner. This process enabled the designer to have significant input during construction and the contractor to modify the design to suit his specific experience and techniques. This reduced the risks on the project to a minimum and led to the successful completion of this undertaking.

REFERENCES

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