Dundas Street Crossing of Sixteen Mile Creek

A Field Spliced, Post-tensioned Precast Concrete Girder Bridge

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Abstract:

Precast concrete girders are often chosen for short and medium span crossings because of their excellent economy. For most bridges, girder lengths are typically governed by local transportation restrictions; however, increased span lengths facilitated by field spliced girders reduce the number of piers required, which in some applications will eliminate in-water work.

At the Dundas Street crossing of Sixteen Mile Creek in Oakville, Ontario, innovative use of a custom gantry system facilitated placement of 61 metre long, field spliced, post-tensioned precast concrete girders. The three 61 metre main spans consisted of three individual pre-cast prestressed concrete girder segments. These segments were joined together on-site using cast-in-place field splices and post tensioning cables in splicing beds located behind each abutment. The splicing beds facilitated seven girders simultaneously, corresponding to each of the girder lines within the new bridge. Using a gantry system, all seven girders in each span were sequentially lifted and longitudinally launched within a single day. After placing all of the girders and casting the diaphragms, the multi-span continuous 276 metre long girders were post-tensioned. This paper presents a design narrative for this field spliced, post-tensioned precast concrete girder bridge followed by a description of the construction process with special emphases on girder erection and temporary works.

Key words: Field spliced girders, post-tensioned bridges, longitudinal launch, gantry system, accelerated construction methods

INTRODUCTION

Reconstruction and widening of Dundas Street (Regional Road 5) from four lanes to six lanes, between Neyagawa Boulevard and Proudfoot trail in the Town of Oakville, Ontario, is currently under construction. As part of this work the existing five-span steel deck truss bridge over 16 Mile Creek is being replaced with two new precast spliced concrete girder bridges. These new structures will provide three lanes and a sidewalk for both east and west bound traffic.

In order to maintain the current four lanes of traffic during construction, replacement of the existing bridge was undertaken in two phases. In Phase I, which was completed in 2008, the first bridge was constructed immediately south of the existing structure. In Phase II, traffic was shifted to the new south bridge and the existing truss bridge was demolished and replaced with the new north bridge. Completion of the north bridge (Phase II) is expected in the Fall of 2011. This paper is limited to presentation of the south bridge with special mention of the means and methods employed for placement of the field spliced precast concrete girders.

Figure I: Placing 61 metre long, field spliced, precast concrete girders using an overhead gantry

Precast concrete girders are often chosen for short and medium span crossings because of their excellent economy. Standard precast girder bridges involve the erection of the prefabricated girders onto piers and then casting the deck slab. 'Spliced' girders are used when the spans exceed the maximum allowable shipping length and weight for local roads. In Ontario, the maximum precast concrete girder length governed by transportation restrictions is usually about 43 to 45 m; accordingly, spans longer than 45 m are typically made up of two or three individual girder segments which are spliced together via continuous post tensioning cables through the segments to make up each span of the bridge.

Multiple options exist for installation of precast concrete girders. For short spans, placement by crane is common practice but as span lengths increase, alternate methods of girder erection need to be considered. Use of an overhead gantry allows girders segments to be unloaded on site and spliced without the use of large mobile cranes and also provides a safe method for girder placement. Construction of temporary bents at splice locations has also been used to facilitate multi-segment girders.

Figure II illustrates two examples of the erection of field-spliced post-tensioned precast concrete I-girder bridges. For the Eglinton Avenue Credit River Bridge in Mississauga, Ontario, segments were spliced together in place using temporary bents at splice locations while construction of the Hwy 407 Bronte Creek Bridge in Oakville, Ontario employed a full span launching truss.

(a) Girder erection using temporary bents

(b) Girder erection using a launching truss

Figure II: Placement of field spliced post-tensioned precast concrete I-girders

This paper includes a structural narrative for a field spliced post-tensioned precast concrete I-girder bridge followed by a description of on-site construction methods employed at 16 Mile Creek including; girder transportation, temporary works, and girder placement using an overhead gantry.

STRUCTURAL NARRATIVE

During the Class Environmental Assessment Study, a number of different structure types and span arrangements were investigated. Two preferred alternatives were identified: a 5-span slab on spliced post-tensioned prestressed I-girder bridge and a 7-span conventional (not spliced) slab on prestressed I-girder bridge. Even though preliminary cost estimates completed at that time indicated that the five span solution would be nominally more expensive, it was identified as preferred because it would have superior aesthetics, less environmental impacts, and less risk with respect to fluvial geomorphology.

On this basis, the chosen span configuration was 46.0m – 60.96m – 60.96m – 60.96m – 46.0m, for an overall structure length of 274.88m, similar to the length of the existing structure.

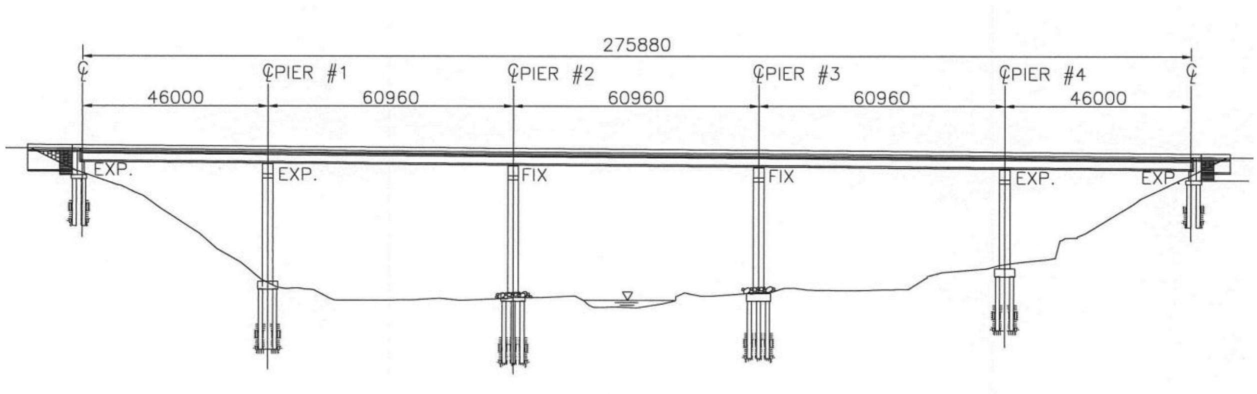

Figure III: Elevation of the South Bridge, Dundas Street Crossing of 16 Mile Creek

Due to the overall length of the bridge (274.88 m) neither integral abutments nor semi-integral abutments were feasible. Therefore, modular expansion joints are located at each abutment to permit movement resulting from thermal expansion, contraction, creep, and shrinkage.

The piers and abutments of the south bridge are founded on concrete caissons socketed in shale bedrock. The abutments for the north bridge are founded on concrete caissons socketed in shale bedrock while the piers are founded on the existing mass concrete footings that supported the previous structure.

The girder length required for the main spans (61 m) was too long for shipping. Accordingly, shorter segments were transported to site where they were spliced and post-tensioned. Each main span girder was composed of three (3) individual precast concrete girder segments and required two (2) splices while each end span girder was comprised of two (2) segments with a single splice. The splices are located near the inflection points in the girder in order to minimize flexural stresses within the splice.

During preliminary design, MRC reviewed three alternatives for splicing and erection of the girders as follows:

1. Splice and post-tension after erecting girder segments onto temporary bents by crane. A temporary bent would be required at each splice for a total of 8 bents per bridge – 2 in each main span and 1 in each end span.
2. Splice and post-tension girder segments on the ground to make up each span length and then erect spliced girders by crane onto piers/abutments.
3. Splice and post-tension girder segments on grade near the approach at one end of the bridge to make up each span length. Erect spliced girders by sliding/rolling into place from the approaches using a temporary launching truss.

Based on discussions and a site meeting with one of the leading girder fabricators in Ontario (Pre-Con) and crane operators, alternative 2 was the expected to be most economical. While all of the three alternatives were feasible for the north bridge, existing aerial Hydro lines south of the south bridge were too close to permit crane erection from the valley which eliminated alternatives 1 or 2 for the south bridge. Accordingly, it was anticipated that the girders for at least the south bridge would have to be launched while any of the methods noted above could be considered for the north bridge.

Notwithstanding the above, the contract was structured to allow as much flexibility as possible with respect to the method of erection. This permitted the successful contractor to choose the method that would best suit their equipment, material, and expertise.

Structure Cross Section

The new Sixteen Mile Creek crossing will be comprised of twin structures. The cross-section of each bridge will include the following:

- Median barrier wall
- 1.5 m left shoulder
- Three traffic lanes (3.65m – 3.65m – 4.20m)
- 1.0 m right shoulder
- Concrete parapet wall between road and sidewalk
- 3.0m combination sidewalk / bicycle pathway.
- Bicycle height railing at outside of sidewalk

The resulting overall width of each structure will be 18.05m. Each bridge has seven (7) CPCI 2450A girders with constant depth, spaced at 2.55 m on centre. The clear distance between each structure will be 5.21m. This will permit future widening of Dundas Street into the median with one additional lane in each direction (total 8 lanes) separated by a 2.0 m wide raised median.

Construction Staging

The new south (eastbound) bridge was constructed while maintaining traffic on the existing truss bridge. The south bridge was constructed without the south sidewalk and parapet wall to accommodate all four lanes of Dundas Street during construction of the north (westbound) bridge. After completion of the north bridge and transferring westbound traffic back onto the north bridge, the sidewalk, parapet wall and outside railing of the south bridge can be completed.

When the bridges require rehabilitation in the future, traffic would have to be reduced to two lanes in each direction. The rehabilitations would proceed in two stages, one half of each bridge at a time while maintaining two lanes of traffic on the other half. This will require removal of the sidewalks and parapet walls on each bridge at that time.

Durability

For enhanced durability, the median barrier walls, parapet walls and sidewalks are constructed using concrete with Everdure Caltite. Caltite is an admixture which incorporates a hydrophobic pore blocking ingredient which reduces absorption and permeability of concrete. This allows the use of unprotected reinforcing steel.

The deck and the tops of the abutments are constructed with high performance concrete and epoxy coated reinforcing steel in accordance with current MTO guidelines. The deck is waterproofed and paved. 30 MPa concrete was used for the piers and foundations.

Girder Analysis and Design

The bridge was designed in accordance with the Canadian Highway Bridge Design Code CAN/CSA-S6-00. The girders were analyzed for the various stages of construction using the finite element analysis software MIDAS Civil to take into account the non-linear time dependent effects due to creep, shrinkage, relaxation, and elastic shortening.

Specified concrete strength for the girders is 50 MPa. All prestressing strands are low relaxation seven wire strand, grade 1860 MPa. The girder segments are prestressed during fabrication with size 13 (12.7 mm nominal diameter) prestressing strands in the bottom flange. The segments are designed as simply supported to resist their own self-weight.

The girders are post-tensioned on site in two (2) stages. In the first stage, the individual girder segments which made up each span were spliced and post-tensioned in splicing beds located at each approach. The girders were then erected using an overhead gantry. Once all the girders were erected and the splices at each pier complete, post-tensioning along the full length of the bridge was performed. The cast-in-place concrete deck was placed after the stage two post-tensioning. Placing the concrete deck after the girders are post-tensioned means that prestressing force is largely retained within the girders which will make future deck replacement less complicated and was necessary to ensure that the specified deck grades were met.

Stage I Post-Tensioning

For the stage 1 post-tensioning, girders were designed as simply supported to resist their self-weight. The Stage 1 post-tensioning consisted of two (2) draped tendons located in the girder web. The tendons have a parabolic profile with the tendon near the mid-height of the web at the ends of the span length and in the bottom of the web at mid-span. Each tendon is comprised of 12 - size 15 (15.24 mm nominal diameter) prestressing strands and is sheathed inside a 90 mm O.D. bright steel rigid, corrugated duct. The tendons are anchored at the ends of the span length in end blocks, where the web is thickened for a short distance to accommodate the anchorage. The cast-in-place splices between segments are comprised of 160mm wide 50 MPa high performance concrete. The Stage 1 post-tensioning tendons were stressed when the concrete in the splices reached 40 MPa. After the tendons were stressed, the ducts were grouted. When the grout in the ducts reached 20 MPa the girder was ready for placement.

Stage II Post-Tensioning

For the Stage 2 post-tensioning, the girder was designed as a continuous beam to resist the dead load from the wet concrete deck using the section properties for the naked girder and to resist the superimposed dead loads and the live loads using the composite section properties of the girder and deck. The Stage 2 post-tensioning consists of three (3) draped tendons located in the girder web. The profile of the Stage 2 tendons is a series of parabolic segments with the tendons in the upper half of the web at the abutments, near the bottom of the web at each mid-span, and at the top of the web at each pier.

The tendons are anchored in the end blocks at the abutment ends of the girder. Each tendon is comprised of 12-size 15 (15.24 mm nominal diameter) prestressing strands and is sheathed inside a 90 mm O.D. bright steel rigid, corrugated duct. The girders are connected at the piers with a 50 MPa cast-in-place high performance concrete closure section and diaphragm. The Stage 2 post-tensioning was stressed when the concrete in the closure sections at the piers reached 30 MPa. Grouting of the ducts was performed after the tendons were stressed. When the grout in the ducts reached 20 MPa, placement of the cast-in-place concrete was permitted.

ON-SITE CONSTRUCTION

Girder segments were transported to site by semi-tractor with the girders being supported by a jeep at the tractor end and dollies at the rear of the girder as shown in Figure IV. Girder transportation for the south bridge at 16 Mile Creek was provided by the precast girder supplier.

(a) Semi-tractor with jeep to support girder **(b) End of girder supported by transport dollies**

Figure IV: Transportation of precast girder segments for 16 Mile Creek South Bridge

Coordination between the precast supplier and the bridge contractor was important to ensure that girder segments were loaded in the proper direction for off-loading on site. Correct orientation of the girders during shipment was important because the gantry system did not have the ability to rotate girders. Upon receipt, girders were backed into a narrow access road which was parallel to the splicing bed. Girders were lifted using the overhead gantry and placed into the splicing bed.

Allowing the contractor to choose and design their own temporary works encourages them to apply their specific expertise and allows the contractor to make use of their preferred means and methods. For the south bridge at 16 Mile Creek the following temporary works were used during construction; an overhead gantry for girder placement, two splicing beds, and a temporary work bridge.

Custom Gantry

The gantry used for girder placement allowed for transverse movement to suit each of the seven girder lines as well as longitudinal movement to suit the length of the splicing bed plus half of the total bridge span, see Figure V. Providing a gantry system which served only half the bridge presented better economy in comparison to a system which could have served the entire bridge length, even with consideration for two splicing beds.

To pick the girders, the gantry lifted at two points using triple cylinder hydraulic rams, as illustrated in Figure V. Nylon straps were shackled to lifting eyes in a steel member at the top of the rams and to steel strand which were cast into the top of the girders in an inverted ‘U’ configuration. The base of each lifting ram was supported on a roller which was guided on the top flange of a heavy overhead beam enabling transverse movement of the girders.

Figure V: Overhead gantry for lifting and placing field spliced precast concrete girders

A rail was installed along either side of the new bridge to allow for longitudinal movement. On the north side of the new bridge the rail was supported on the existing truss bridge while a temporary support truss was installed to support the south rail. The contractor’s speciality erection engineer evaluated the existing truss bridge to ensure its capacity to support girder loads during the launch and also designed the cantilever supports for the temporary truss which supported the south rail.

Following preparation of the girders within the splicing beds, the contractor was able to successfully launch one complete span consisting of seven girders within a single seven hour period.

Splicing Bed

Due to transportation restraints, girders were shipped to site in segments which were spliced together to provide girder lengths which matched the bridge spans. Three girder segments were required for the 61 metre spans while only two segments were required for the 46 metre approach spans. Segments were supported on temporary concrete footings which were placed at the girder ends and at each splice location; accordingly, four spread footings were required for a girder with three segments.

In this operation there is a benefit realized by the contractor when the girder segments are consistent in length throughout each span. For example, when only two segments are required for the approach spans consideration may be given for choosing lengths which are consistent with two of the three segments chosen for the main spans. If alternate lengths are specified, an additional footing is required in the splicing bed.

Figure VI: Splicing bed for joining precast concrete girder segments on-site

Figure VI illustrates the splicing bed with a complete span of seven girders. The splicing bed for field spliced precast concrete girders supports the segments during splicing and provides girder stability throughout the first stage of post-tensioning.

Temporary Work Bridge

At 16 Mile Creek a temporary access bridge was required for construction of valley piers west of the Sixteen Mile Creek and for erection of the supporting truss for the north rail of the gantry. Use of temporary access bridges is common for large bridge projects; some examples include the Highway 407 Bronte Creek Bridge, Highway 403 Credit River Bridge, the Upper Middle Road 16 Mile Creek Bridge, the Derry Road Credit River Bridge and the Sheppard Subway East Don River Bridge. In all cases, the design concept, rather than a detailed design, was developed together with detailed operational and design constraints in the contract. This approach has been endorsed by Conservation Authorities in the past and has proven to be successful, efficient, and enables the contractor to utilize their own design and materials.

For the construction of the south bridge at 16 Mile Creek, a Bailey Bridge™ was chosen by the contractor; however, Harvey et. al (2002) presents several types of low volume road bridges commonly used in western Canada which provide cost effective alternatives to the traditional modular truss bridges used for temporary bridge applications.

CONCLUSION

The new south bridge for the Dundas Street crossing of Sixteen Mile Creek successfully employed a custom overhead gantry system for placement of the field spliced, post-tensioned, precast concrete girders. The 61 metre main spans were spliced on grade near each approach using three individual girder segments then longitudinally launched. After placing of all the girders, longitudinal post-tensioning was completed along the entire bridge length.

The design of field spliced post-tensioned girder bridges includes analysis of the various stages of construction and takes into account the non-linear time dependent effects due to creep, shrinkage, relaxation, and elastic shortening. Structuring tender documents which allows the contractor flexibility in choosing the erection method which suits their expertise and equipment promotes healthy completion between bidders and also allows opportunities for decreased project costs.

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