CASE STUDIES FOR STEEL BRIDGE ERECTION: CONVENTIONAL, LATERAL SLIDES, AND INCREMENTAL LAUNCHING

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BIOGRAPHY

Matthew works as a Project Engineer in the bridge division of MMM Group where he provides specialized experience in preliminary and detailed bridge design, rapid bridge replacement, accelerated bridge construction, and constructability review.

Prior to joining MMM Group Matthew worked on-site with the Surespan Group during the incremental launch of the Athabasca River Bridge and the lateral slide for Mount Hunter Creek Bridge.

Doug Dixon is a Senior Bridge Engineer and Project Manager at MMM Group with over 30 years of experience in the planning, preliminary and detail design of all aspects of new bridges and bridge rehabilitations. His experience includes movable and fixed highway bridges, pedestrian and rail carrying structures. Doug has extensive large span bridge experience having worked on most of the International Border Crossings between Ontario and the United States.

Doug's experience also includes projects delivered by a variety of methods, including design-bid-build, design-build, Construction Manager General Contractor (CMGC) and a variety of other approaches.

SUMMARY

Several different methods exist for erection of steel bridges including conventional crane placement of girders, lateral slides, and incremental launching. Each bridge site is unique. Determining the most appropriate erection method during preliminary design is often influenced by several factors including project schedule, crane access, environmental regulations, construction staging, and allowable traffic impacts.

This paper provides project specific references and key considerations for design engineers and bridge owners to assist in the decision making process for preferred erection methodologies during initial planning and preliminary design of complex steel bridges.

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Abstract

Several different methods exist for erection of steel bridges including conventional crane placement of girders, lateral slides, and incremental launching. Each bridge site is unique. Determining the most appropriate erection method during preliminary design is often influenced by several factors including project schedule, crane access, environmental regulations, construction staging, and allowable traffic impacts.

Three erection methods are presented using the following case studies: Conventional erection for the three-span 180m long haunched steel plate girder Mackenzie River Bridges, Northern Ontario; the lateral slide for the 192m long four-span haunched steel plate girder Kenogami River Bridge in Northern Ontario; and the incremental launch for the 122m long two span Highway 14 Sombrio Bridge on Vancouver Island, British Columbia. Following the case studies, design considerations for each of the three steel bridge erection methods are discussed. This paper provides project specific references and key considerations for design engineers and bridge owners to assist in the decision making process for preferred erection methodologies during initial planning and preliminary design of complex steel bridges.

Conventional Erection: Mackenzie River Bridges

Figure 1: Mackenzie River Bridges Steel Erection

The Mackenzie River twin bridges (Figure 1) were completed in 2011 as part of the TransCanada Highway realignment and twinning near Thunder Bay, Ontario.

The three-span variable depth steel plate girder structure is supported by cast-in-place concrete abutments and piers. Span arrangements are 50m–80m–50m and the section for each bridge consists of five steel plate girders varying in depth from 1800mm at the abutment to 3000mm at the piers.

Figure 2: Three Girders Bearing on Pier

As shown in Figure 2, only three of the five girders are supported at each pier. A steel plate diaphragm transfers the loads from the outer girder lines to the three interior girders.

Fabrication of the precast deck panels and the structural steel was tendered as separate contracts in advance of the main contract in order to facilitate the timely delivery of these components and to facilitate construction of the new bridges in one construction season.

Construction Access – Temporary access roads (Figure 3) were located between the twin bridges enabling the delivery of the girder segments to crane pads that were positioned close to the piers. Cranes were also located behind the east and west abutments.

Figure 3: Mackenzie - Construction Access Road

Each girder segment was delivered to the site in its upright position using dollies that were pulled by a semi-tractor.

Engineered Lift Plans – An engineered lift plan and erection drawings were prepared by the steel erection sub-contractor which detailed exact locations for cranes, maximum lifting radii, erection sequence, crane utilization for all critical lifts, custom rigging, and all temporary works required for girder stabilization and ironworker access.

Each of the steel plate girders for the Mackenzie River Bridges has four bolted splices. All girder splices were completed in the air without the use of temporary supports. To provide ironworker access, temporary work platforms were provided at each of the splice locations.

Several different crane types and configurations were utilized within the lift plan; the largest cranes included an 800t taxi (DEMAG AC 700) and a 500t conventional crawler (Manitowac 2250). To increase the reach of the crawler, a tail swing assembly with wheeled counterweight was added as shown in Figure 4.

Figure 4: Manitowoc 2250 with MAX-ER 2000

Lateral Slide: Kenogami River Bridge

In 2006, the Kenogami River Bridge was replaced with the a new structure (Figure 5) located along the same alignment as the previous bridge. Given the remote location, the nearest detour would have resulted in an approximate two-hour drive. Re-alignment of the highway was considered but site constraints did not allow for a new alignment.

The replacement structure is a composite concrete slab on steel plate girder bridge with span arrangements of 40m–56m–56m–40m. The structure width of 12.5m provides a sidewalk along the north side and accommodates two lanes of traffic.

Figure 5: Kenogami River Bridge

Construction Staging – Staged construction was used to facilitate a single lane of traffic throughout the entire project.

During the first stage, new piers and temporary bents were constructed with traffic maintained on the north side of the existing bridge. Two of the new girders were erected on the temporary bents and a 4.9m wide section of deck was placed. Traffic was then switched to the new section of deck for stage 2 while the existing bridge was demolished.

The remaining three girders were erected in their permanent location during stage 3 along with placement of a 7.0m wide section of the deck. Traffic was then shifted onto the new girders and the two girders previously erected on the temporary bents were slide laterally to their permanent locations on the new substructure. A small closure pour was then placed to complete the bridge deck.

Figure 6: Temporary Bents for Kenogami

Temporary Bents – The temporary support frame was constructed using vertical H-piles with steel angle cross bracing as shown in Figure 6.

A custom cap beam was fabricated using steel plate. At each pier, 6 Dywidag bars were used to post-tension the cap beam for the temporary bent to the new pier cap. Steel angles provided lateral restraint for the new girders on the temporary bents.

Lateral Slide – The lateral slide for Kenogami River Bridge was performed using Hilman rollers guided within a structural steel channel located at each abutment and pier (Figure 7).

Figure 7: Slide Path with Guided Hilman Rollers

Two-way hydraulic jacks provided a push-pull system that provided the lateral force for the slide (Figure 8). The push-pull mechanism enabled precise positioning of the structure prior to lowering the bridge onto its permanent bearings.

The lateral slide path was in line with the permanent bearing locations allowing the new abutments and piers to provide support for the girders during the slide.

Once the girders were in their permanent alignment, an incremental jacking scheme enabled removal of the steel channel and Hilman rollers followed by installation of the permanent bearings.

Figure 8: Lateral Slide Push-Pull Jacking System

Incremental Launch: Highway 14 Sombrio Bridge

The Highway 14 Sombrio Bridge is located on Vancouver Island between Port Renfrew and Sooke. This new bridge was constructed several hundred metres upstream of the existing bridge to provide an improved highway alignment which removes several hair pin turns. A significant constraint at this site was restricted access due to a steep ravine that was more than 20m deep.

After a thorough review of alternatives, the designers determined that a 122m long composite steel plate girder bridge with unequal spans of 40m and 82m was the preferred structure for this site. Options for a second pier were investigated but it was determined that a second pier was not feasible due to slope instability and poor construction access. The deep ravine prevented conventional erection of the structural steel but not the use of an incremental launch.

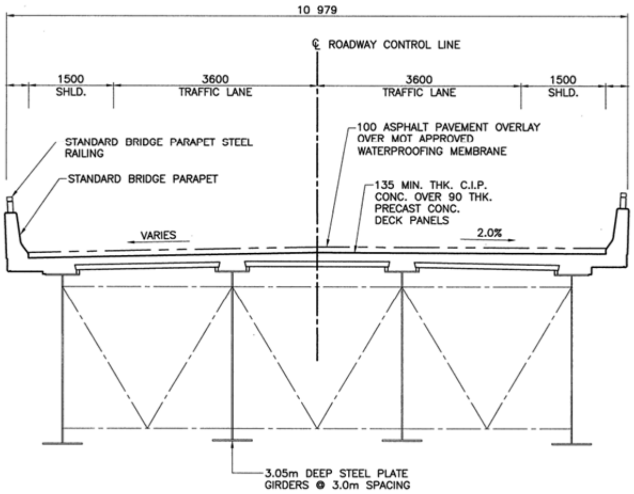

Figure 9: Sombrio Bridge – Typical Section

The section for the Sombrio Bridge (Figure 9) consists of four 3.05m deep steel plate girders spaced at 3.0m with partial-depth precast panels and a cast-in-place topping slab.

This bridge is on a constant grade of 1.00% ascending north to south. The girders were launched uphill from the north abutment.

Procurement Method – The conventional design-bid-build procurement method was used for the Highway 14 Sombrio Bridge. During preliminary and detail design the prime consultant confirmed general feasibility for the incremental launch; however, the design for the launch was completed by the contractor's erection engineer under the scope of work for steel erection.

Allowing the contractor to design this incremental launch enabled the successful contractor to fully utilize their custom launch equipment and previous erection experience. Benefits associated with a launch system designed by the contractor include increased bid competition and reduced risk for the owner. A performance-based Special Provision was included in the contract which specified the requirements for the launch and the erection engineer.

Steel Detailing – For a successful and cost effective bridge launch, it is critical to provide continuity (in elevation and plan) along the mid-section of the bottom flange for each girder.

The detailed design for the Sombrio Bridge included structural steel details specifically designed to facilitate the incremental launch. These details include constant depth girders with web plates coped to provide matching elevations for the underside of the bottom flange at all splice locations and multiple steel plates at the underside of the bottom flange to facilitate each field splice.

The inclusion of multiple splice plates for the underside of the bottom flange allowed the field splice to be bolted in the launch bed using plates along the outer edges of the bottom flange while not obstructing the centre section of the girder which was used as the point of contact for the Hilman rollers during the launch as shown in Figure 10.

Figure 10: Bottom Plates for Field Splice

Laydown Area – A designated staging area to facilitate the launch bed was provided at the north approach. In this staging area the steel girders were erected in segments prior to each sequence of the launch.

In determining the size of the required laydown area consideration was given for the length required for a feasible launch bed to provide adequate counter balance during the initial sequences of the launch and a width that would facilitate erection of the girders while also providing crane pads/corridors for each lift and temporary access roads for girder delivery.

Means and Methods – Several different launch configurations were investigated by the contractor's erection engineer for this site; Trowland and Singh[1] provide a detailed description of the specific means and methods chosen for the incremental launch of the steel girders for the Sombrio Bridge.

All four girder lines were launched simultaneously with temporary roller supports provided for each girder line at two locations within the launch bed and at the north abutment and pier. Figure 11 shows the girders in their cantilevered state during the launch.

Figure 11: Incremental Launch - Sombrio Bridge

A winch was used for the launch with single anchor points located at the north abutment and at the tail end of the girders. A block which facilitated a six-part line was rigged at the abutment anchor point to increase the pulling capacity of the winch.

To overcome deflection of the leading cantilevered end of the girders the steel erector utilized an innovative method which did not require a launch nose. Typically an inclined launch nose (or similar device) is attached to the girders to facilitate initial touch down at each support and to provide the means for overcoming the cantilever deflection.

For the Sombrio launch the erector used a controlled technique designed by their erection engineers. The girders were launched slightly higher than the pier and then rotated down to make contact on the rollers at the pier (Figure 12).

Figure 12: Hilman Rollers and Lateral Guides

In the final sequence of the launch the girders had a free cantilever length of 81m, precast concrete deck panels were used as counter balance. To overcome tip deflection in the final launch sequence a crane set up behind the south abutment (Figure 13) was used to lift the tips of the girders.

Figure 13: Crane Lift to in Place of Launch Nose

Design Considerations for Steel Bridge Erection

Each bridge site presents its own unique set of constraints, which are becoming increasingly difficult to satisfy using conventional erection methods. Accordingly, many bridge engineers and contractors are finding that lateral slides and incremental launching are effective methods to meet challenging project objectives. Each of these three erection methods are presented in the following sections with key design considerations noted.

Conventional

Unless project-specific constraints require that a lateral slide or incremental launch be used, conventional erection usually presents the most cost effective method for steel bridge construction.

Most bridge professionals are familiar with the requirements for conventional erection and are confident in determining the suitability of a site for conventional construction. During the early stages of preliminary design, specific consideration is typically given to construction access, crane placement, and girder stability during erection.

Construction Access – Temporary access roads to facilitate equipment mobilization and delivery of girder segments to their respective lifting points are reviewed to confirm construction feasibility.

Crane Placement – Potential crane locations for all lifts are identified and the necessary crane size, crane pads, work bridges, or barges required are reviewed during the preliminary design phase.

Single Girder Stability – If the crane size and laydown areas restrict lifts to a single girder (as opposed to two girders braced together) then stability of the single girder during erection needs to be considered. For curved plate girder bridges lifts of two girders together are often required for girder stability during erection.

Lateral Slide

The lateral slide method consists of erecting a bridge superstructure parallel to its final alignment and then rolling or sliding the structure to its permanent position. The lateral slide method may be used to enable rapid bridge replacements(2), facilitate complex traffic staging(3), allow existing bridges to serve as detour routes during bridge replacement(4), or reduce lifting radii for heavy lifts(5).

Bridges that are installed, or removed, using the lateral slide method require temporary supports and a slide mechanism.

Temporary Supports – The location for temporary supports for lateral slides are often positioned in line with the permanent bearing locations. If the intention of the lateral slide is to facilitate rapid bridge replacement, consideration may be given to offsetting the temporary supports from the permanent bearing locations. Slide paths that are offset from the permanent bearing locations may increase the size of the substructure or require additional temporary works during construction; accordingly, the cost-benefit of an offset slide path should be reviewed to determine the preferred approach.

If the lateral slide path is positioned in line with the permanent bearing locations then the launch rail is commonly elevated above the bearings. This requires temporary support seats which can be difficult and time consuming to remove during the incremental jacking that is required to lower the superstructure onto its permanent bearing locations. Alternatively, a slide path can be designed to be integral with the new bridge so that the slide path remains as part of the permanent structure.

Having the temporary supports and transverse launch rails offset from the permanent bearing locations allows the new superstructure to be slid into position at an elevation just above the permanent bearings. This eliminates the complications associated with conflicts caused during removal of the launch rail; however, it also comes with an added cost as additional temporary supports may be required directly in front of the abutments and piers.

Slide Mechanism – Key components for the slide mechanism include a slide path, a push and/or pull system, and rollers or low-friction pads.

The slide path can be very simple, consisting of regular steel H-pile or channel sections. Hydraulic jacks, winches, and cranes have all been used successfully as the drive mechanism for lateral slides. When a crane is used, a block is required at the end of the slide path to re-direct the vertical pull of the crane to suit the horizontal movement required for the slide. Rollers or low-friction pads, which travel within a launch rail, enable the slide.

Incremental Launch

Incremental launching refers to a scheme in which the structural steel is erected at the bridge approach then pushed out to its permanent position. The use of incremental launching for steel bridges is not a new method; however, its ability to accelerate the critical path activity during construction and reduce environmental impact is leading to a renewed interest in this steel erection method.

Key components required to facilitate an incremental launch include a launch pad, pushing assembly, girder support, lateral guides, a mechanism to correct cantilever deflection, and launch-friendly details for the structural steel.

Launch Pad – A launch pad is a staging area directly behind one or both abutments in which the steel segments are erected prior to each increment of the launch.

The length of the launch pad needs to be designed so that it can facilitate adequate counterbalance of the structure during the initial stages on the launch prior to touch down at the first pier. For the Athabasca River Bridge(6) the launch pad was 122 m, twice the length of the 61 m approach span. Methods to reduce the length of the launch pad include placing additional counter balance on the tail end of the girders and/or using a slender launch nose.

Pushing Assembly – Many methods have been successfully used as the pushing mechanism for incrementally launched bridges. Some of these methods employ: large stroke hydraulic jacks (direct push), strand jacks with wire rope, winches, or heavy construction equipment such as tracked dozers.

Girder Support – Girders are supported during the launch using rollers or low-friction pads. Support locations typically correspond to the permanent bearing locations at each abutment and pier as well as temporary supports within the launch pad.

Due to restricted access to the bearing seats after the steel erection is complete, there is often a preference to install bearings prior to the launch. If bearings are installed prior to the launch, a temporary steel saddle may be used to support the rollers above the bearings. After completion of the launch the girders are jacked down and seated on the permanent bearings.

Given the need to house the temporary steel saddle and multiple jacks, consideration should be given during detailed design to the size of pier cap and abutment seat. Compact pier caps and abutment seats make it extremely difficult to detail the temporary works required for a bridge launch.

Lateral Guides – Lateral support is required throughout steel erection and during each sequence of the launch. During the launch, lateral guides not only provide support for loads such as wind, they also provide a guide system to keep the girders in line.

Since the Hilman rollers need to pass through the bottom flange splice plates, it is highly recommended to have active lateral supports. This has been successfully achieved on launches by housing a hydraulic jack within the lateral guides.

If possible, lateral guides should be positioned in girder bays that do not have diagonal wind bracing at the bottom flange level.

Cantilever Deflection – Prior to touch down of the girders at each pier, significant deflection of the cantilevered end will occur. Methods successfully used to correct this tip deflection for previous launches include the use of a tapered launch nose, a custom steel frame with hydraulic jacks, or the use of alternative methods such as those employed for the Sombrio launch[(1)].

The bridge designer should be aware that temporary loads will be introduced to the piers during the launch and should ensure that the erection engineer checks the piers for these temporary conditions.

Steel Detailing – Detailing structural steel to facilitate launching is critical for a successful and cost effective launch. Constant depth girders should be chosen and all girder splices (including shop and field splices) should be detailed so that the undersides of the bottom flange for each girder segment is at the same elevation.

For field splices, multiple splice plates are required on the underside of the bottom flange so that the splice plates may pass through the Hilman rollers without conflict as shown Figure 10. Preference should be given to two outer splice plates; however, three splice plates may be used but access for ironworkers to install the centre splice plate should be considered along with the associated cost.

Consideration should also be given during detail design to provide a minimum of 150mm vertical clear distance from the bottom flange and any horizontal components within girder bays such as K-bracing and intermediate diaphragms to allow for a lateral guide system as described above.

Design Considerations

During the early stages of preliminary design of steel bridges, site specific constraints should be identified with consideration given to the lateral slide or incremental launch methods as means to meet project objectives.

Owners and prime consultants may consider project-specific constructability review workshops which include engineers and contractors familiar with the requirements for successful lateral slides and incremental launches to assist with development of cost-effective and constructible designs.

For design-bid-build contracts the designer should consider a performance based specification for the lateral slides and incremental launches which allows the Contractor to design all temporary works and the lateral slide or incremental launch system. This will allow each Contractor to make full use of their specific expertise and temporary works resulting in competitive bids.

Conclusion

As owners look to new and innovative methods to construct bridges economically and quickly, steel bridges facilitate several proven erection techniques that suit most sites. Conventional erection, lateral slides, and incremental launching all have merits for a specific site depending on access, site topography, and equipment availability.

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Mackenzie River Bridges key participants:
Owner: Ministry of Transportation Ontario
Designer: MMM Group
General Contractor: Teranorth Construction
Steel Erection Subcontractor: ES Fox Structural and Bridge Division
Erection Engineering: Domson Engineering and George Pauls Engineering
Steel Fabricators: Structal Bridges (WBL) and Central Welding (EBL)

Kenogomi River Bridge key participants:
Owner: Ministry of Transportation Ontario
Designer: MMM Group
General Contractor: Kiewit Corporation
Engineering for lateral slide: MMM Group

Hwy 14 Sombrio Bridge key participants:
Owner: BC Ministry of Transportation
Designer: MMM Group
General Contractor: Windley Construction
Steel Erection Subcontractor: Surespan Construction
Erection Engineering: Infinity Engineering Group
Steel Fabricator: Rapid-Span

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