HEAVY MOVABLE STRUCTURES, INC.
SEVENTEENTH BIENNIAL SYMPOSIUM

October 22-25, 2018

Orthotropic Steel Deck for Short Span Movable Bridges

Éric Lévesque & Maxime Ampleman
Canam-Bridges Canada Inc.

MARRIOTT'S RENAISSANCE HOTEL AT SEAWORLD
ORLANDO, FLORIDA

Abstract

Recently, the superstructure of the Kingston Mills swing bridge (2017) and the Brighton swing bridge (2018), two small bridges in Ontario, have been replaced and rehabilitated. The replacement/rehabilitation of these structures involved interesting challenges. In fact, the superstructure had to be light, balanced and compatible with the existing components. Also, the demolition and reconstruction of these bridges had to be done during winter, in a reduced schedule in order to clear the waterway for the opening of the boat season. This paper intends to present two recent examples of using orthotropic steel deck solutions for short span movable bridges.

Introduction

At the 2016 HMS Symposium, we presented an article about the use of orthotropic steel deck (OSD) for the rehabilitation of the Hastings swing bridge (fig 1), involving a complete replacement of the superstructure. Since then, two other short span movable bridges were rehabilitated using OSD: the Kingston Mills swing bridge (2017) and the Brighton swing bridge (2018).

Figure 1: Completed Hastings swing bridge (www.pc.gc.ca)

The Kingston Mills swing bridge, rehabilitated in 2017, is a 1,380 square foot – 56.5 feet (17.2 meters) long by 24.5 feet (7.5 meters) wide - structure located up north of the city of Kingston in Ontario, Canada. For that project, a partial replacement of the superstructure was needed. In fact, existing main girders (twin-girders system) were conserved and only the floorbeams and the bridge deck on the cantilever section were replaced. On the short side of the pivot, cast-in place concrete was used to ensure the proper counterweight. The fabricated OSD weights 61.1 lbs/ft^2 (299 kg/m^2).

The Brighton swing bridge, replaced in 2018, is a 5,015 square foot – 155.3 feet (47.3 meters) long by 32.3 feet (9.8 meters) wide - structure located east of the city of Brighton in Ontario, Canada. The project required a complete replacement of the superstructure, including the main girders and the central pivot.

These two projects have many challenges in common, as they both required winter rehabilitation without interfering with the navigational boat season. Also, the weight of the new structure had to be low enough for the existing elements (mechanical and electrical elements and substructure).

Orthotropic Steel Deck

Orthotropic steel decks (fig. 2) have many advantages that make them competitive for movable structures. In fact, their lightweight compared to concrete structures can significantly reduce substructure and mechanical elements. Also, the possibility of composite action may reduce the weight of the main girders and achieve longer spans.

The Canadian Highway Bridge Design Code CAN/CSA S6-14 suggests that a solid deck of lightweight construction in movable spans be considered in order to improve protection of the infrastructure and superstructure of movable bridges.

An orthotropic steel deck is shop-fabricated under a rigorous quality-assurance and quality control program, offering a service life well beyond 75 years. With easily defined geometry, an orthotropic steel deck can offer increased moments of inertia, more effectively and efficiently controlling deflections. Also, the fact that the OSD is shop-fabricated allows reducing the schedule on the field and then limit the impact on traffic.

OSD also allows the contractor to apply a thin antiskid (and asphalt if desired) wearing surface, allowing for an even quicker installation on the jobsite.

Figure 2: Typical orthotropic deck section

The orthotropic steel deck may have closed (U or V sections) or open ribs (Plate, inverted T, L, C, etc.) (fig. 3). Welding of closed ribs is more complex to perform as only one side is accessible. A partial penetration joint is required. However, closed ribs are more efficient for the transfer of traffic loads and, in general, they lead to a lighter structure than those with open ribs.

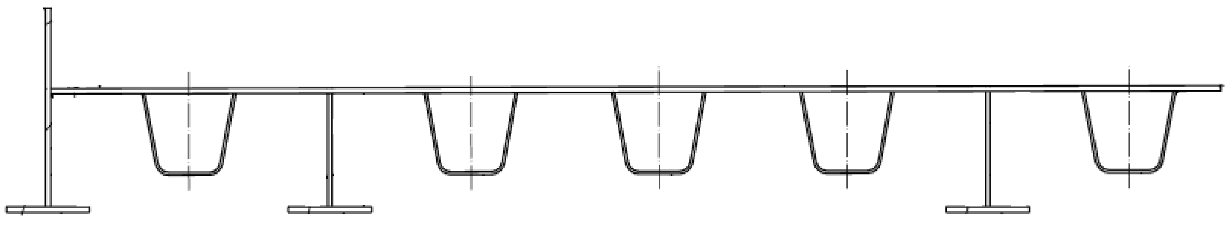

Figure 3: Closed ribs (U) and open ribs (inverted T) used in Kingston's (OSD)

Particularities of the Projects

Both projects had the common challenge that the structure had to be replaced/rehabilitated during winter (fig 4). So, the shop-fabrication had to start during the fall season in order to be completed during winter. As the orthotropic superstructure is shop-fabricated, the timeframe of work on field was reduced and both bridges were completed on time for the boat season.

Figure 4: Installation of OSD panels to the existing twin girders during winter – Kingston

Also, the Kingston Mills and the Brighton swing bridges have been pre-assembled in shop to ensure the fitting between the different elements when delivered on field.

Shop Pre-assembly

Kingston Mills Swing Bridge

Even if the Kingston Mills swing bridge was a partial rehabilitation of the superstructure, a complete pre-assembly in shop has been done. To do so, the two existing main girders (twin-girders) were reproduced in shop, including their connections to the new floorbeams that support the new OSD. Every bolt hole of these reproduced connections were precisely located by a surveyor. Then, the whole assembly of the two orthotropic steel deck panels with their floor beams were completed.

Brighton Swing Bridge

As the Brighton swing bridge was a complete replacement of the superstructure, it was possible to proceed to a complete pre-assembly in shop of the whole bridge (fig. 5). The total pre-assembly comprised 6 OSD panels with integral girders and 1 central pivot formed by a steel box with a top OSD section (fig. 6).

Figure 5: Completed pre-assembly of the Brighton swing bridge

Figure 6: Central pivot - Brighton swing bridge

Design/Fabrication

Kingston Mills Swing Bridge

The new deck is transversely composite, which means that the underneath floorbeams and the OSD panels are connected with sufficient bolts to develop the composite action. It was then possible to reduce the size of the floorbeams, which have the function of carrying the traffic loads and dead loads of the OSD panels to the twin-girders – one on each side of the bridge. Figure 7 shows the cross section bolted to the floorbeams.

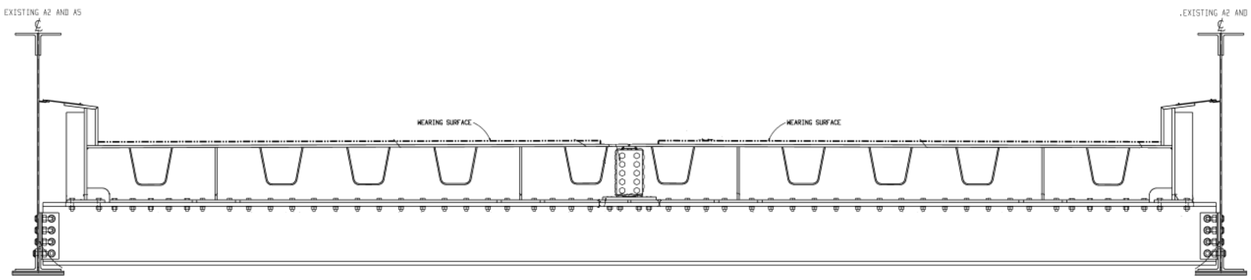

Figure 7: Cross section - Kingston Mils Swing Bridge

The client requested a thin antiskid wearing surface. So, for the longitudinal joint between the two deck panels, a welded connection was chosen. The welded connection was completed during winter. In the case of the Hastings swing bridge (2016), the owner asked for an asphalt wearing surface. So, a bolted longitudinal joint with countersunk bolts was chosen as the solution in order to fasten the assembly. Figure 8 presents the bolted longitudinal joint used for the Hastings swing bridge on the left, and the welded longitudinal joint on the right side. The end of the welded connection between closed ribs and transverse beams was achieved using the wrap around filet weld (fig. 9).

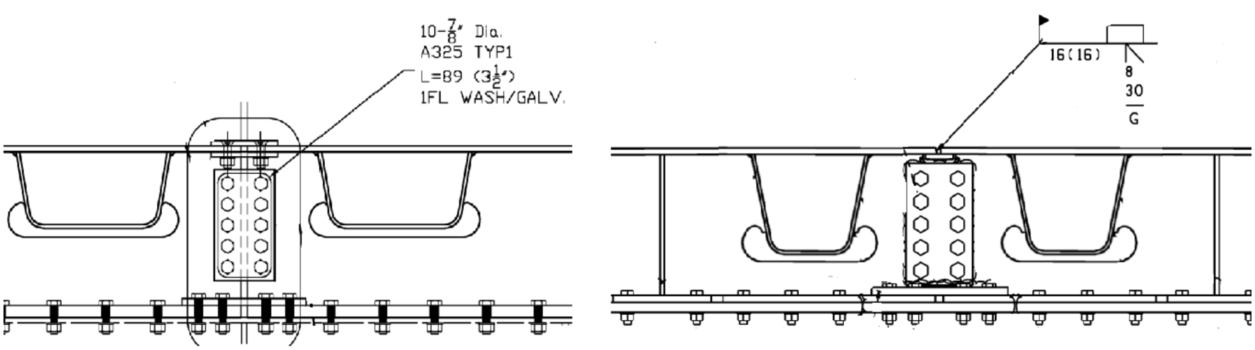

Figure 8: Bolted longitudinal joint (Hastings) on left and welded longitudinal joint (Kingston Mills) on right

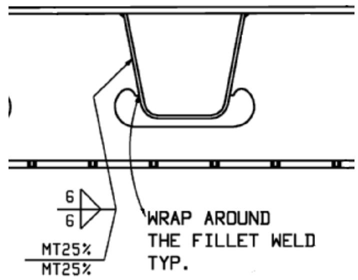

Figure 9: Rib to transverse beam connection

The deck plate was 5/8 inch (16 mm) thick. 5/8 inch (16 mm) or thicker deck plate allows to reduce the fabrication cost as the re-working is limited. In fact, thinner deck plate may undergo significant deformation during the rib-welding process. So, the more economical solution is not always the lighter structure. When optimizing the different elements, the designer should consider both the weight and the fabrication hours, including the potential re-working.

Brighton Swing Bridge

The Brighton Swing Bridge is composed of an integral orthotropic steel deck with main girders. The longitudinal inverted T's are acting as the main girders, with an increased web depth and a variable inertia. Figure 10 presents one of the six deck sections that composes the bridge, along with the central pivot.

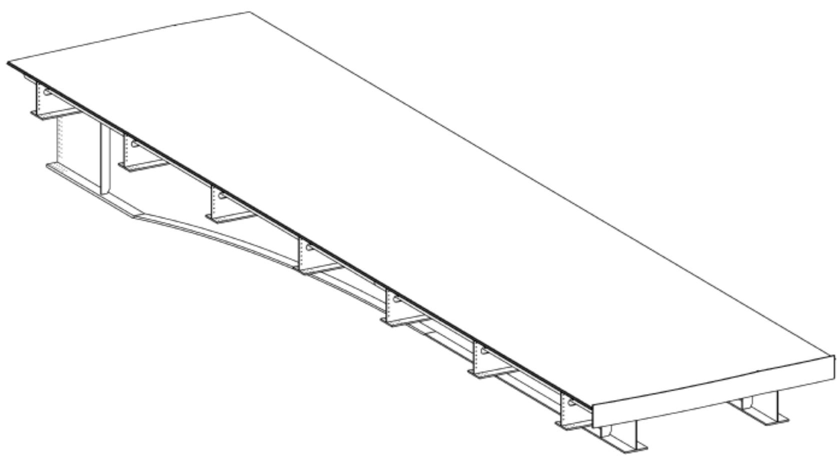

Figure 10: 1 of the 6 deck section composing the Brighton swing bridge

The fact that the deck sections are completely integral with the girders allows a very quick replacement on site. Indeed, instead of assembling different small elements, the bridge is composed of only 7 main elements – 6 deck sections and 1 central pivot, to be joint mainly by bolting. The deck plates are welded on site

As for Kingston, the welded connection between closed ribs and transverse beams was achieved using the wrap around filet weld. The rib to deck connection used an 80% penetration – 8 mm deep in a 10 mm plate (fig. 11).

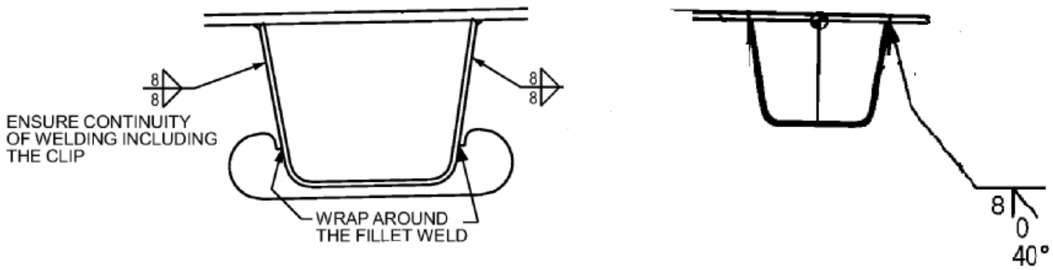

Figure 11: Ribs welding – Brighton Swing Bridge, 2018

The client asked for an asphalt wearing surface, so in that case, a bolted longitudinal joint could have been used to fasten the deck sections. However, a welded longitudinal joint was the solution retained (fig. 12).

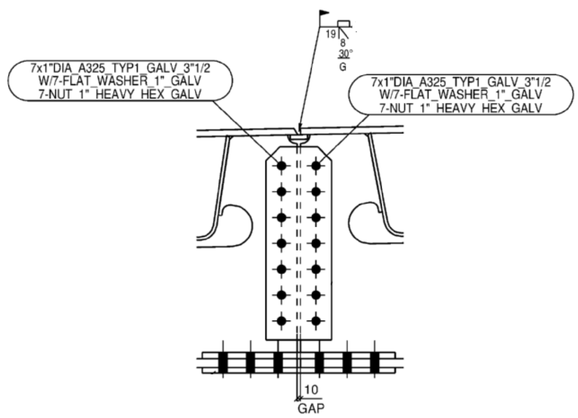

Figure 12: Welded longitudinal joint – Brighton Swing Bridge, 2018

Balance Testing

For the construction of a swing movable bridge, it is important that the bridge weight is balanced both sides of the pivot. So, each piece "as fabricated" is weighed in order to ensure the proper counterweight (fig. 13).

Figure 13: Balance used before every delivery

Conclusion

This paper presented two recent bridges rehabilitation/replacement using orthotropic steel deck – the Kingston Mills swing bridge (fig. 14) and the Brighton swing bridge. Key points to the OSD success can be summarized as follows:

A. Fabrication in shop under controlled conditions;
B. Lightweight structure;
C. Winter installation;
D. Quick replacement and ABC projects;
E. Pre-assembly in shop;
F. Composite effect.

Figure 14: Kingston Mills Swing Bridge