Orthotropic steel deck is a viable option for rehabbing movable bridges working on tight schedules.

ORTHOTROPIC Deck Delivers

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AS STATES AND OWNERS consider how to address our nation's infrastructure issues and increase the long-term performance of their assets, their first reaction is typically to consider options in their comfort zone.

However, there are other proven cost-competitive alternatives that can be effective when it comes to re-decking long-span steel bridges. One such option is the use of prefabricated orthotropic steel deck (OSD) panels.

These modular panels employ a lightweight deck to reduce the overall weight of the superstructure and can be designed to sit on existing piers and foundations. The geometry of these deck panels can also be designed to increase the total height of the deck, increasing its moment of inertia in specific areas to reduce deflection. Ultimately, a panel can be installed with a thin, anti-skid wearing surface (with an optional asphalt overcoat) that can provide a service life in excess of 75 years.

The technology was recently employed on a swing bridge in Hastings, Ontario. Built in the early 1950s, the bridge was a key fixture in the community and a major link over the Trent-Severn Waterway. But after years of exposure to de-icing salts and in-service operation, the bridge was nearing the end of its serviceable life and was de-rated based on its condition.

In 2014, Parks Canada Agency, with Public Works and Government Services Canada, retained Associated Engineer-

Project Time Line

Fall 2015. The contract is awarded, and fabrication of the steel superstructure begins immediately and continues nonstop on a 24-hour cycle through the end of 2015 and into early 2016. Site work progresses in parallel, as the owner would not allow de-mobilizing the existing bridge until fabrication was sufficiently advanced to ensure the completion date could be met. The fabrication schedule is achieved, and demolition of the existing bridge commences on time.

January 2016. The existing structure is removed, resulting in a 34-mile detour. The contractor immediately starts rehabilitation of the concrete foundations. During the rehabilitation, steel superstructure fabrication is completed for the girders and OSD deck, including all shop welding.

March 2016. The completed assembly is shop-painted and delivered to the site just as rehabilitation work on the existing foundations is completed.

ing, Ltd., to undertake a full inspection, load evaluation, life-cycle analysis, preliminary design and detailed design of a rehabilitation or replacement structure.

The existing span was arranged with a cantilever span of approximately 56 ft and a back counterweight span of 28 ft. The structural system was comprised of two primary steel through-girders, a floor beam system, a central pivot girder, a concrete back-span deck acting as the counterweight and an open-grid deck. The west side of the structure includes

▲ The new bridge in full-service condition.

◄ The underside of an OSD panel during installation.

▼ The OSD panel is positioned in place prior to bolting the bottom flange of the transverse floor beam to the steel superstructure.

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A view of the steel superstructure prior to installing the OSD. The transverse floor beams of the OSD were used as a template to drill matching holes in the superstructure above.

A view of the longitudinal bolted splice between the orthotropic steel deck panels before asphalt was added. The panels were delivered with an anti-skid waterproofing membrane that was preinstalled by the fabricator for durability and worker safety during the wet winter months.

a sidewalk, but an east sidewalk was never installed as it would have conflicted with marine traffic using the canal.

In 2012, Associated Engineering performed an initial site investigation, load evaluation and inspection, which indeed confirmed that the structure was approaching the end of its serviceable life. The existing load posting was confirmed and preliminary design options were evaluated to estimate the rehabilitation cost. The optimal solution called for replacing the superstructure with steel and rehabilitating the substructure, which was anticipated to reduce the overall project schedule by one month.

The original bridge relied on an open-grid deck, a fatal feature that allowed de-icing materials to accumulate on the steel components below, leading to corrosion. To prevent these corrosion issues in the new bridge, the engineer evaluated closed deck solutions to better control the de-icing fluid run-off from the roadway surface. When evaluating a closed-deck solution, the overall weight of the structure is critical, as it impacts the loads imparted on the newly rehabilitated foundation, and both concrete and steel closed deck options were considered, including precast concrete, cast-in-place concrete, concrete-filled open-bar grating and OSD configurations.

Winter Ready

The OSD option was selected, as it was the only one that offered the optimum combination of light weight, durability, stiffness and geometric flexibility. Additionally, for this particular project, one of the biggest advantages of OSD was that the structure could be prefabricated in a temperature-controlled environment, limiting the amount of winter concrete work while accelerating the delivery schedule.

The waterway is closed to traffic for four months in winter, so all construction to replace the superstructure

Updated Weld Penetration Requirements for Rib-to-Deck Welds

Last year, AASHTO voted to modify the weld penetration requirements to 60% minimum penetration and added a requirement for the weld throat to be greater than the rib thickness. The previous requirement of 80% penetration (70% minimum) forced fabricators to employ an expensive balancing act using welding procedures with enough energy to reach the joint root while not burning through the root. This change improves constructability, provides more flexibility and reduces the chances of melt-through or burn-through; it also reduces the potential for hot cracking. The updated weld requirements are based on fatigue test results reported by J.M. Barsom and J.W. Fisher, who demonstrated that if the new requirements are met, fatigue performance was at least equal to the previous 80% requirements. (The study, *Evaluation of Cracking in the Rib-to-Deck Welds of the Bronx-Whitestone Bridge*, will be published in the American Society of Civil Engineers' *Journal of the Structural Division*.)

Even with these improvements, research continues on the rib-to-deck weld. The FHWA recently presented to the AASHTO/NSBA Streel Bridge Collaboration a regression analysis of rib-to-deck welds, correlating weld performance to key parameters such as penetration percentage and fit-up gap. The Collaboration is also developing a proposed experimental evaluation of the weld to establish bounds for fit-up gap tolerance. Each of these studies will further improve understanding of this important weld.

By Duncan Paterson, PE, PhD, Cincinnati Bridge Section Manager, Professional Associate, HDR and to rehabilitate the substructure had to take place within this tight window. This limitation required that the steel superstructure, including the deck, be fabricated, delivered to the site and installed as soon as the substructure work was completed. Movable bridges always require tight tolerances to work effectively, and the steel OSD solution allowed an extremely high level of geometric precision to fit the new structure to the existing roadway profile.

The new superstructure configuration consists of primary girders, floor beams, a central pivot pier, a steel counterweight, OSD, an asphalt wearing surface and a pedestrian sidewalk on the west side of the structure. The new movable swing bridge is nearly 84 ft long and 27 ft wide and has a surface area 2,200 sq. ft.

This configuration posed a challenge because the new superstructure geometry had to fit on existing foundations, resulting in a structure with a center of gravity that was longitudinally and transversely offset from the geometric center of the structure. Based on their past experience, the designers knew that the OSD offered the best solution to address this issue. Thus, the team committed to integrating the OSD into the design from day one, and models and all connection and interface details between the OSD and steel were provided in the initial design stages. Performance specifications for the OSD were developed and included in the final contract specifications; the OSD components were designed to act compositely with the structure's floor beam system both in the open and closed position. The welding specification for the rib-to-deck plate welds required a practical and achievable partial joint penetration. According to the AASHTO *LRFD Bridge Design Specifications* (2012 Edition), a target penetration of 80%—with 70% minimum—was respected (see sidebar at left for more). The deck plate and closed rib details were specified to be designed by the fabricator to ensure economy, stiffness, fatigue life, fabrication quality and system durability.

Splendid Splice

The OSD layout and design were chosen with shop fabrication, shipping and erection issues in mind. With input from the fabricator, this OSD design completely eliminated onsite welding of the deck plate by incorporating a longitudinal bolted joint splice. By bolting this splice instead of welding it, the contractor saved valuable time by limiting delays related to winter conditions that would prevent welding.

The bridge components and steel counterweight units were field-bolted together, then the OSD, with a shop-applied high-performance waterproofing membrane, was field-bolted to the steel superstructure. Next, the assembled unit was swung into place and paved before the contractor performed the final balancing and commissioning. Vehicle traffic returned to the roadway almost a month ahead of schedule, and vessel passage was achieved in time for the opening of boating season on the Trent-Severn system.

The project highlights a successful implementation of an OSD design for a surprisingly complex structure with a compressed winter construction schedule. A large portion of its success is due to the contractor's and fabricator's involvement in the preliminary and final design of the OSD and final pre-shop assembly of the steel superstructure and OSD to confirm geometric acceptance prior to delivery to the site. ■

*Visit **https://youtu.be/R3kgSJV2Xr8** for a short video on the installation of the Hastings Swing Bridge.*