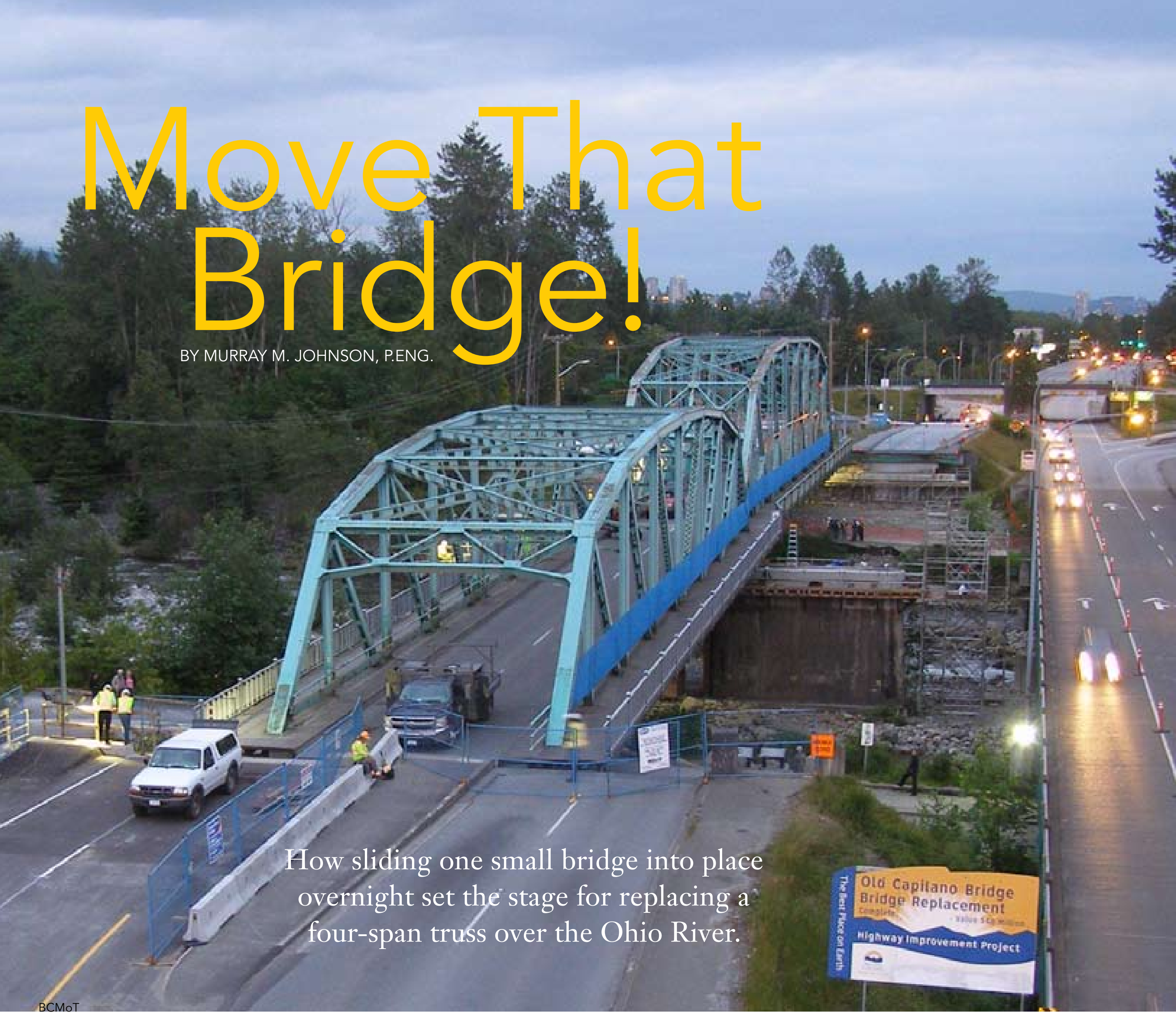
Move That Bridge!

BY MURRAY M. JOHNSON, P.ENG.

How sliding one small bridge into place overnight set the stage for replacing a four-span truss over the Ohio River.



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The Old Capilano River Bridge halfway through the sliding operation (moving right to left in photo). Note one lane of westbound traffic being accommodated on normally eastbound bridge at far right.

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REPLACING A VITAL BRIDGE carrying busy traffic loads over water, with limited or onerous alternate routes, is a serious undertaking. It generally requires either a new alignment, some form of staged construction that maintains partial traffic while the bridge is replaced around it, or construction of a temporary detour bridge. Existing road connections, built-up urban areas, other infrastructure, right-of-way limitations, or other site constraints often preclude a new alignment. Staged construction usually disrupts traffic and is always more expensive than building the new bridge in one pass, and not even structurally feasible for some bridge types. Sometimes a detour bridge may be built with a lesser length or to a lower standard, such as over a seasonally variable watercourse, but often the scale of the detour bridge required matches that of the permanent bridge itself. This can dramatically increase the project cost and delay or even prevent an owner from proceeding with it due to funding limitations.

One innovative technique for providing the detour for a bridge replacement, while keeping the original alignment, involves using either the old bridge or the new superstructure as the detour and


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➤ The Old Capilano River Bridge during sliding, with bridge halfway from old river pier onto temporary pier. A one-minute time lapse video of the slide is available on YouTube at **http://bit.ly/zT6dZ5**.

employing lateral sliding of the superstructure during construction to reposition it during a short closure. Lateral sliding of bridge superstructures has been used as a construction technique on smaller girder bridges such as highway overpasses, but is less common on larger spans.

In June 2010, the 80-year-old Capilano River Bridge, in West Vancouver, British Columbia, was slid sideways onto a temporary pier and abutments during an overnight closure and reopened to traffic in the morning, becoming an instant, low-cost detour while a replacement bridge was built in the original location. Near the end of 2012, the new Milton Madison Bridge, spanning the Ohio River between Kentucky and Indiana, will be closed for just a few days while it is slid sideways, from the temporary piers upon which it is being constructed onto rehabilitated and enlarged original piers, after serving as the traffic detour while the old bridge superstructure is demolished.

In both cases, the sliding technique allows the projects to be built while minimizing disruption to traffic, accelerating construction, and reducing costs considerably. The difference is one of magnitude: The two-span, 430-ft, 1,280-ton Capilano River Bridge slide will be scaled up dramatically at Milton Madison, where four steel truss spans measuring 2,430 ft and weighing 15,260 tons will be slid into place.

The Capilano River Bridge

The Capilano River Bridge carries all westbound traffic on Marine Drive from North Vancouver and off the iconic Lions Gate Bridge from Vancouver, over the environmentally-sensitive Capilano River. Originally built in 1929 as a single 250-ft steel truss span with short jump spans at each end, a second 180-ft steel truss was added after a 1949 flood washed out the west bank, abutment and jump span and widened the river.

By 2009, the two shoulderless narrow lanes of the bridge were a bottleneck for the more than 25,000 vehicles using it each day. Pedestrian and cyclist accommodation was poor, transit improvements were needed, and the bridge was deemed to be functionally obsolete. The bridge owner, the British Columbia Ministry of Transportation and Infrastructure (BCMoT), had longer-term plans for replacement of the bridge when funding help was suddenly offered under the Canadian federal government's infrastructure stimulus program.


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▲ Workers monitor progress, keeping a close eye on tight clearances, as the Old Capilano River Bridge slide continues.


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➤ Truss sliding runway at the Old Capilano River Bridge piers during the sliding operation.

▼ The Old Capilano River Bridge in operation as the detour while new bridge substructures start to take shape. Wood hoardings at both ends of site accommodated pedestrian traffic through the bridge site throughout construction.


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New steel girders being launched from the Capilano River's east bank, over the river pier and closing in on west abutment.

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The completed New Capilano River Bridge.

The catch: in order to receive the funding, project completion was required in less than two years, including design and construction. This tight deadline was further complicated by additional schedule constraints related to the upcoming Winter Olympics, during which roadwork was banned, and very limited in-stream working windows due to the salmon-bearing values of the river.

The BCMoT dove into planning for the project. With the help of a study by Buckland & Taylor Ltd. (B&T), international bridge engineers headquartered in North Vancouver, British Columbia, the solution chosen was to slide the old bridge superstructure upstream onto temporary supports to become the construction detour, thereby exposing the original alignment for demolition of the old abutments and pier and construction of a new, wider bridge. Less than three months from the conception of the project, construction of detour approaches was well under way and tenders had been called for building a temporary pier.

Two months later, in September of 2009, the temporary pier had been finished within the short "fish window" period, and left for the main contractor to slide the bridge onto in 2010. This pier, which would be the sliding runway as well as support the bridge in temporary service, used a forest of steel pipe piles drilled into the river bed, topped by steel W-shape cross-caps and a heavily reinforced concrete cap/sliding beam which was directly connected to the old concrete pier.

Design of the new bridge continued through the winter while the temporary approaches, using modular concrete blocks and geogrid-reinforced fills, were completed. A construction contract was awarded and sitework began on April 1, after the Olympics shutdown.

Schedule again was a factor, as the old bridge had to be slid out of the way in time to allow in-stream work on the new bridge to take place during the summer "fish window." To speed the process, the required design for the sliding was included in the tender documents with only details, equipment and work procedures to be added by the contractor.

Moving Old Trusses

The old steel trusses were supported on pinned shoes at each bearing location, some fixed, some on steel roller nests. After installing steel sliding tracks along each runway, the trusses were jacked up during short night closures and sliding shoes—steel plates with PFTE pads—inserted under each bearing. Old rollers were removed and replaced with stacks of steel plates. Although the two truss spans were structurally independent, the 1949 truss shoehorned onto the pier around the existing 1929 truss. That meant the bearings at the pier were nested and had to be dealt with together, and a common sliding shoe was inserted here.

The bridge was rotated in plan as it was slid, to suit the required alignment of the detour, so a different pulling speed was required at each of the three support lines. Moving the bridge was done using pairs of hydraulic jacks pulling on high-strength threaded bars, cycling up to 6 in. at a time.

The sliding design eliminated vertical jacking requirements at the conclusion of the slide, saving money and especially time. The detour approach roadways had been carefully positioned so that when the bridge arrived in the new location, it was vertically aligned and traffic could flow as soon as the deck joints were covered. The PTFE sliding elements that were the lateral sliding element became the longitudinal sliding bearings for the bridge in its new service.

Prior to the scheduled sliding date, a test slide was required, moving the bridge 1 in. then stopping, in order to test equipment, communications and control. After a few minor adjustments, one Saturday evening traffic on the bridge was diverted and the bridge closed for the sliding operation. The steel tracks were greased and the bridge was moved along its curved path, held on course by a single guide track at the pier, arriving in the detour location less than 6 hours later. The remainder of the night was spent installing restraints at the bearings, covering the deck joints, and repositioning roadway barriers. The bridge was reopened to traffic the following morning, with many drivers hardly aware that it had been moved. With the site now available, construction started immediately on the new bridge.

The most economical design for the new bridge was determined to be a two-span continuous steel plate girder structure with a cast-in-place composite deck and integral abutments, without deck joints. The single pier in the river and both abutments are supported on steel pipe piles. Because the profile of the roadway over the bridge includes a symmetric vertical curve with a rise of about 2 ft, by keeping the girder bottom flange horizontal the girder depth varied from 5 ft at the abutments to 7 ft over the pier, neatly accommodating the higher bending moment demands over the pier. Five steel plate girders of 50 ksi weathering steel at 12-ft spacing support a 57-ft-wide cast-in-place concrete deck carrying three lanes of traffic, shoulders and a wide shared pedestrian and cycle path. The contractor chose to launch the steel girders across the river from one bank, bolting two of the three sections together, pushing them part-way out, then bolting on the remaining section in the limited site space before finishing the launch.

Kicking it Up a Notch With a Design-Build Innovation

Design-build bids were solicited for the Milton Madison Bridge replacement over the Ohio River near Madison, Ind., in June 2010. The joint owners of the bridge, the Kentucky Transportation Cabinet and the Indiana Department of Transportation, had studied the bridge replacement issue extensively with their engineers and had arrived at the concept of rehabilitating most of the existing piers and replacing the superstructure. Although the existing steel truss bridge, built in 1929, is very narrow, without shoulders or sidewalks, deteriorating, and functionally obsolete, it is the only crossing in a 72-mile stretch of the Ohio River and is vital to the communities it serves.

Bidders were to replace the entire superstructure with a new wider four-span continuous steel truss bridge with new concrete girder approach spans. Four of the five piers supporting the new main span's superstructure would be rehabilitated existing piers. The roadway and sidewalk requirements, as well as the general dimensions and some design features of the truss, were pre-established to meet the pier constraints as well as the requirements of a public consultation process for replacing the historic but deteriorated bridge. Main truss spans would be 600 ft, 600 ft, 727 ft, and 500 ft, with 48-ft center-to-center of trusses.

Bid documents included a formula to establish the effective bid price. To the contractor's construction price would be added an amount equal to $25,000 per day for every day the bridge was closed, limited to a maximum of 365 days. In addition, two completion dates, September 2012 or May 2013, were allowed, with a deduction of $3.75 million from the effective bid price for committing to the earlier date. A round-the-clock ferry would have to be operated for the closure period of the bridge.

Walsh Construction Ltd., Crown Point, Ind., teamed up with Burgess & Niple, Inc. (B&N), Columbus, Ohio, and Buckland & Taylor to bid the project. B&N would design the approaches and the pier rehabilitation while B&T would perform both the design and the construction engineering for the steel main spans. In addition to coming up with efficient designs for the new permanent structure, the challenge for the bid design team was finding an innovative solution that would eliminate the need for a long bridge closure and reduce construction risk associated with schedule.

The team developed a bold solution building on B&T's recent success with sliding the Capilano River Bridge. The existing bridge would remain open to traffic while beginning the pier rehabilitation, while the new bridge superstructure would be completely constructed alongside on temporary piers. Traffic would then be diverted onto the new structure and the old superstructure and pier tops demolished to make way for the completion of the new pier caps. Temporary access ramps for traffic would allow the new approaches to be completely built in their final position. Finally, when all was ready, the bridge would be closed for a few days at most and the entire new superstructure slid into final position.

With a bid price of $103.7 million, a bridge closure bid of only 10 days, and the earlier completion date, Walsh was the successful bidder. The design of the new steel truss bridge, a 2,430-ft continuous truss built using 8,200 tons of high-performance 50 ksi and 70 ksi steel, with a continuous concrete deck on floating bearings, is remarkable but beyond the scope of this article.

Tons of Temporary Steel

The temporary works associated with the plan are extensive and involve a total of some 3,200 tons of steel piling and fabricated steel. In accepting the concept of operating public traffic on a bridge on temporary supports, the owners required that the design criteria be essentially the same as for a permanent structure. The most significant consequence of this is related to the ship impact

➤ New Span 2 trusses for the Milton Madison Bridge being assembled on barges at Kentucky bank, shown one-third complete.

▼ Overall view, looking from Indiana to Kentucky, of the existing Milton Madison Bridge (left). New Span 2 trusses being assembled on barges at Kentucky bank, shown halfway complete.


Deborah Crawford


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▼ New Span 2 trusses for the Milton Madison Bridge being assembled on barges at Kentucky bank.


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Walsh Construction

Welded steel barge impact frames for Temporary Pier 3 on the Milton Madison Bridge project, doubling as pile driving template.

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Welded steel box beams for the Milton Madison Bridge temporary piers.

loadings required for the temporary piers, because long trains of heavily loaded barges operate on the Ohio River. Complicating this is a highly variable water level at the bridge location. These factors result in a temporary pier design with massive steel barge impact frames at three levels, heavily connected to the strengthened permanent pier stems and protecting the six 36-in.-diameter steel pipe piles supporting the temporary towers. These will include 1,250 tons of steel in barge impact frames and temporary pier towers, as well as 1,400 tons of steel pipe piles.

The two truss spans over the main river channel are being assembled on barges against the Kentucky shoreline, and will be floated out one at a time and lifted some 80 ft into place using strand jacks. To accommodate the lifting, three of the temporary piers will have lifting towers added on top, while the end of one span will be lifted by jacks perched on top of the new truss top chord. Once lifted, the truss spans will be set on heavy steel box girders, 101-in. deep and 78-in. wide, which double as the top caps for the temporary pier supported on two levels of sub-caps and, eventually, as sliding runways. Hillsdale Fabricators, St. Louis, is producing some 520 tons of these temporary girders, using plate up to 3-in. thick as well as associated support steel.

Once the two central truss spans are lifted and secured, the side span trusses will be erected piecemeal, using cranes on barges and land, cantilevering toward the river banks. Intermediate erection bents will take the load near river's edge and jack the trusses to allow them to land on the two end temporary piers. Padgett, Inc., New Albany, Ind., is fabricating 75 tons of temporary sliding girders and pier caps for these end piers. Following completion of steel erection, the new bridge superstructure will be completed with concrete deck, sidewalk, barriers, and temporary expansion joints, and linked to the temporary approach ramps to start carrying traffic.

Sliding

The sliding will come after demolition of the old bridge superstructure and completion of the new pier caps. Similar to the Capilano River Bridge, the new bearings and the sliding process have been designed so that on completion of sliding, no vertical jacking is required. When the PTFE element built into the truss bearing for lateral sliding arrives in its final position, it will simply be fastened to the embedded bearing plate.

The sliding track at each pier will include the top flange of the temporary pier girders, the masonry plates, and sliding plates set on the pier concrete between the bearing plates. Bearings that in permanent service will be sliding bearings will be temporarily locked together for the lateral slide, and also as for Capilano, the entire structure will be guided along a path at the center pier, allowing thermal movements to occur in both directions during the course of the slide.

On sliding day, the entire superstructure will be moved 55 ft upstream to its new position, pulled by strand jacks linked to a computerized, displacement-monitoring control system. One adjacent approach span will also be separately slid into place, and then expansion joints will be completed at the bridge ends and the bridge reopened to traffic in its permanent position.

In meeting the goals of accelerating bridge replacement, providing efficient detours for unrelenting traffic, and building cost-effective new bridges, lateral sliding of bridge superstructures, longer and heavier than ever, is one more tool that designers and builders can employ. The success of the Capilano River Bridge project has helped develop the techniques that are now being used on a much larger bridge, and undoubtedly will be used on many more future bridge projects, as owners and contractors try to meet the demand for faster, more efficient, less disruptive and more sustainable construction. MSC

Capilano River Bridge

Owner

British Columbia Ministry of Transportation & Infrastructure

Structural Engineer

Buckland & Taylor Ltd., North Vancouver, British Columbia

General Contractor

Neelco Construction Inc., Chilliwack, British Columbia

Milton Madison Bridge

Owners

Indiana Department of Transportation and Kentucky Transportation Cabinet

Owner's Engineers

Michael Baker Jr., Inc., Louisville, Ky., and CDM Smith, Indianapolis

Structural Engineer (Main Spans Design and Construction)

Buckland & Taylor Ltd., North Vancouver, British Columbia

Structural Engineer (Pier Rehabilitation, Approach Spans, and Temporary Ramps)

Burgess & Niple, Inc., Columbus, Ohio

General Contractor

Walsh Construction Co., Crown Point, Ind.

Steel Detailer (New Bridge)

Tensor Engineering, Indian Harbor Beach, Fla. (AISC Member)

Steel Fabricator (New Bridge)

High Steel Structures Inc., Lancaster, Pa. (NSBA/AISC Member)

Steel Fabricators (Temporary Works)

Hillsdale Fabricators, St. Louis (AISC Member) and Padgett Inc., New Albany, Ind. (NSBA/AISC Member)