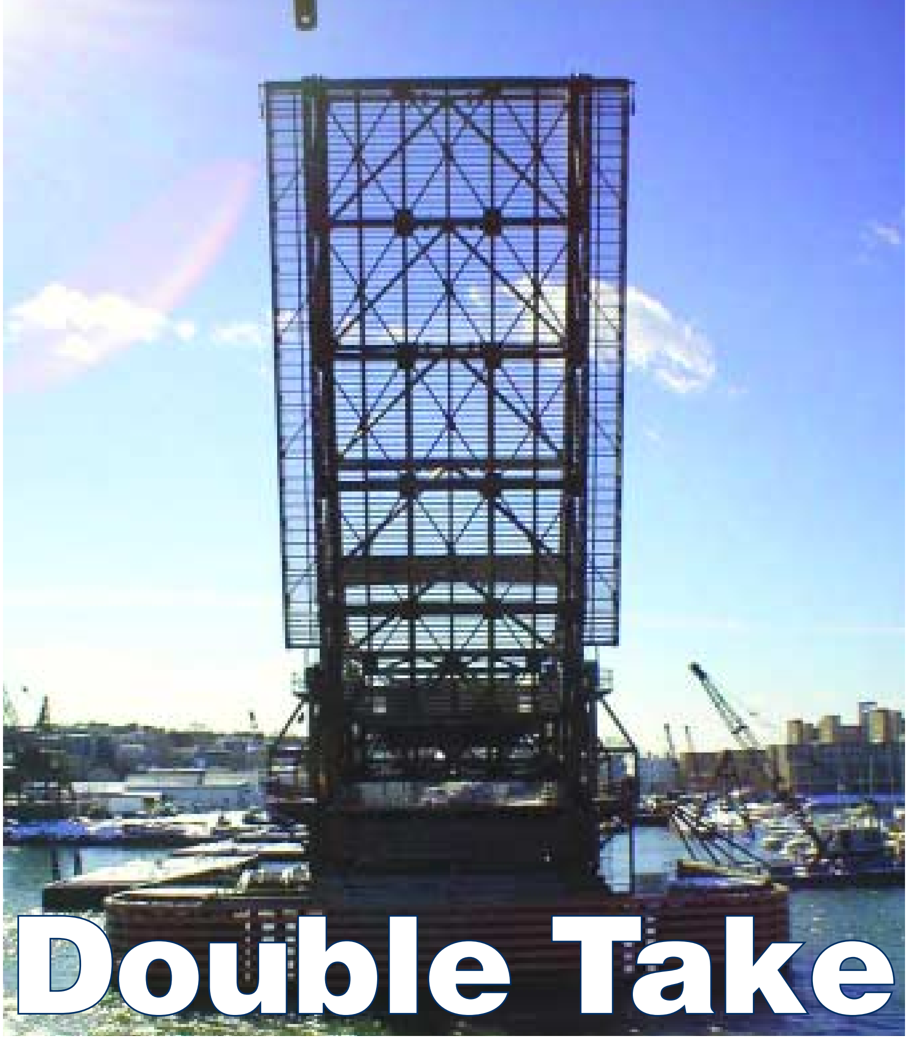


Double Take

Lifting Boston's McArdle Bridge to higher standards meant putting it back into working order and creating easy access for repairs down the road.

By Andrew C. Coates, P.E., Paul M. Skelton, P.E., and David S. Tuckman, P.E.

Constructed in 1953, the McArdle Bridge crosses the Chelsea River in Boston. Over the course of three years, critical repairs made to the McArdle Bridge restored its reliable operation as a vital link to the New England area. This double-leaf, rolling-lift through-truss spans 225′ (center of roll-to-center of roll) and is 65′ wide (out-to-out). The span opens about 1,500 times per year, due to heavy barge traffic delivery of heating oil for New England and jet fuel for Logan Airport. Because dependable operation of the bridge's movable span is vital to the region's economy, its recent rehabilitation was crucial in keeping the span running smoothly.

The bridge's rehabilitation included complex structural repairs to improve the operation of the span, such as jacking the north leaf to realign the span, replacing the segmental-girder flange angles, reinforcing the track-girder flange angles, and replacing the segmental and track castings. These critical repairs took the span out of service and needed to be completed during channel closures, which the U.S. Coast Guard limited to three-and-a-half days. The limited time periods required step-by-step planning and extensive detailing of the repairs.

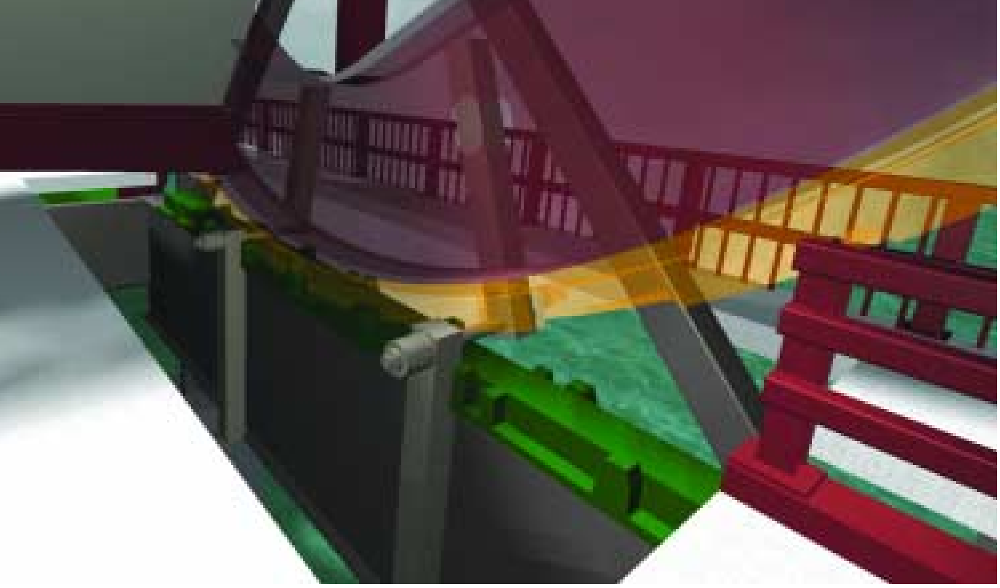
A complete deck replacement, which included structural steel purlin supports and miscellaneous floor-beam repairs, was necessary to strengthen the deteriorated span. Also part of the rehab were new rack and pinions, a new electrical-drive and control systems, a rebuilt control house, and a complete re-painting of the entire bridge.

Rolling Along

A rolling-lift bridge employs the combined actions of rotation and translation of the span (while a trunnion-bascule allows solely for rotation). The geometry of this motion combination can be beneficial, since it allows a larger channel clearance for an equivalent angle of opening. Further, the use of a rolling-lift arrangement permits a lower roadway grade and a smaller substructure to accommodate the swinging motion of the span's counterweight box. The leaf rolls back on a moving radial component (or segmental girder) riding along a fixed horizontal component (or track girder).

While this dual motion of rotation and translation can benefit the span geometrically, it also can hinder operation reliability. One inherent problem with a rolling-lift bridge is its tendency to become misaligned over time. It is essential that the segmental and track castings function properly to assure the span will operate as designed. The McArdle Bridge suffered from misalignment, which allowed the span to "walk" transversely.

The misalignment—a result of the existing segmental and track assemblies' poor condition—caused poor contact between existing members. Large longitudinal and transverse loads from the movement of this 1,500-ton leaf caused the pintles, which maintain alignment on the track casting, to crack and break-off completely. In addition, the segmental girder angles completely cracked, resulting in poor contact with the segmental castings. The wear on these mating members also caused the span to drop, and as a result, the pinion teeth made contact



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with the root of the rack teeth. The pinion, located at the center of gravity of each truss system, is responsible for driving the span open and closed. Any misalignment of the pinion translates to problems with the span's operating machinery.

Getting it Right

Prior to replacement of the segmental and track castings, the span was realigned using jacks and 2½″-diameter A449 studs. Temporary supports were installed to allow for jacking against the inboard side of the track casting. The contact area between the segmental and track casting was cleaned and greased with an extreme pressure lubricant with graphite additives to allow for sliding and to minimize the high transverse loads the span would experience during the jacking procedure.

Once properly aligned, crews performed repair work needed to accompany critical segmental replacement, including strengthening the segmental-girder and track-girder-flange angles. Performed in advance, this work occurred while the span was still operable in order to minimize bridge and channel closures. Existing rivets were removed from the segmental girder, and the existing holes were reamed to accommodate new high-strength bolts. In addition, new angles were bolted temporarily to the segmental girder for later use in strengthening and splicing the new segmental castings.

Open for Business

Installing new segmental castings usually requires bridge closures in order for the angles to be removed, field-drilled to assure proper alignment of the castings for segmental fastening, and reinstalled. Track-girder repairs included stacking new angles on top of the existing flange angles to avoid removal of the existing angles, which would have required closing the bridge. Existing rivet heads were flattened, and new holes were drilled for new bolts. The track-girder and segmental repairs were performed concurrently, thus avoiding bridge and channel closures.

Once the spans were aligned and the required modifications were completed, castings were replaced and adjustments were made to the existing centering device to assure future proper alignment would be maintained in the seated or closed position. The centering device was removed and modified to allow for the newly seated position of the spans. Lug and guide castings of the centering device were removed to perform machine shop work.

Chemical analysis performed on the existing lugs helped develop a suitable welding procedure to build up the lugs with weld metal. The lugs were then machined to allow for the specified clearances. Rehabilitation of the centering device not only assured proper alignment of the span in the seated position but also relieved transverse, or secondary loads from the span lock bars. Lock bars are designed to transfer live-load shear (vertical forces) from one leaf to another. If the centering device is not functioning properly and the spans are misaligned in the final seated position, the lock bars will act to center the leaves when driven into position. Lateral wind loads also can be transferred through the lock bars if not properly aligned. However, this is not the intent of the lock bars' original design.

Basic Upkeep

Over time, an additional transverse load will damage mechanical linkages not designed for multi-directional loads. The load, in turn, can eventually damage the operating machinery of the lock bars. Correct alignment and accurate installation of the centering device are essential-for proper structural and mechanical operations of the span.

The bridge operates and travels on two mating surfaces: segmental castings and track castings. Segmental castings are fastened to the lower truss chord and move with the span as it rolls open and closed. Track castings are fastened to the track girder, which is the fixed end of the two mating surfaces. These help support the bridge as it translates during operation. The span's dead and live loads are transferred through these castings to the foundation of the bridge.

The new segmental and track castings—made of ASTM A27 cast steel, Grade 70-36—were designed using a precise engagement system. If future removal of the castings is required, the castings will allow for easy repair and maintenance. Because most of the rotating effects caused by misalignment would occur at these locations, new gear teeth segments have also been designed to allowing for easy removal.

Unlike the original design, these gear teeth were fastened independently to the segmental casting by tapping ASTM A449, 1¼″-diameter, high-strength cap screws into the casting. If necessary, future rehabilitation would simply require replacement of the gear teeth rather than the entire segmental casting. Both sets of castings were replaced sequentially, half with the span opened, and half with the span closed. All fixed and movable mating surfaces were machine-finished to 125 micro-inches to assure a smooth riding surface during operation.

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All Tied Up

As previously mentioned, the new design allowed for temporary partial replacement during staging sequences. To allow for the replacement of forward segments, a tieback system was used to maintain the span in its opened or rolled back position. Pinion replacement was concurrent with the segmental replacement, necessitating an external support to keep the leaf opened.

Two sets of wire-rope tiebacks were used for this procedure. One set connected the truss top chord to the approach-span girder, while the second set connected the truss lower chord to the fender system. These sets stabilized the position of the span and allowed for completion of work. Precise coordination was essential for the casting replacement since the U.S. Coast Guard limited navigation closures to three-and-a-half days.

During the rollback procedure, the span was raised in elevation with the use of full-width tapered shims attached to the castings. The span rose 1/8″ and successfully re-established a clearance between the rack and pinion, eliminating secondary binding forces that had been affecting the operating machinery. While in the opened position, the racks and pinions were replaced along with other machinery repairs. Once casting replacement was done, the remaining structural repairs to the segmental girder were completed as well. New flange angles were fastened to the new castings using turned bolts or finished body bolts (with a maximum bolt-hole clearance of 0.01″) to further strengthen the existing segmental and track-casting members.

Casting Call

The new castings function more like a gear system than the previous castings, and the result is extremely accurate control of the span during motion and while at rest. The new system assures nearly constant contact between the track and segmental castings in both longitudinal and transverse directions, preventing the span from rotating about the horizontal axis, or "walking" on the track.

Additional miscellaneous structural repairs were performed simultaneously with the segmental repairs. Floor beam and lateral bracing repairs were made, along with an entire replacement of the grid deck and its supporting structural purlin members. Final blasting and painting of the entire superstructure followed the termination of all structural repairs. The three-coat paint system for this project (a MASS Highway Standard Paint System) consisted of a zinc-based primer with Epoxy intermediate and final coating. As with the segmental repairs, proper coordination and staging during these procedures was essential to minimize channel closures and disruption to vehicular traffic.

With the addition of heavier segmental castings and added weight due to the strengthening of the segmental castings and floor beams, extra measures to maintain span balance in the Y-(vertical)-direction were needed. Steel plates were added as necessary to the top chord of the span and the top of the counterweight to raise the span's center of gravity.

Smooth Operator

Close attention to detailing and construction staging helped hammer out the challenges of maintaining navigation during construction of this rolling-lift bridge. The operating machinery, which controls the movement of the span during operation, relies on an accurately balanced leaf in order to function ideally and provide smooth operation. An out-of-balance condition can cause the span to "rack" or skew in its translation during movement and contribute to the possibility of further misalignment. Thus, maintaining proper balance remains essential to the operation of the span. ★

Andrew C. Coates, P.E. is a partner, partner-in-charge and project manager; Paul M. Skelton, P.E. is a partner, partner-in-charge and project manager; and David S. Tuckman, P.E. is an associate at Hardesty & Hanover, LLP.

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