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Emergency Repair of Counterweight Trunnion Pins on the Gloucester Draw Bridge

Giancarlo Schiano E.I.T.
Kevin Ciampi E.I.T.
Herbert Protin P.E.

HDR Engineering Inc.

CARIBE ROYALE
ORLANDO, FLORIDA

Bridge Background

History & Background

The Gloucester Draw Bridge (Gloucester Draw) was designed and constructed by the Strauss Bascule & Concrete Bridge Company of Chicago in 1911 for the Boston and Maine Railroad. The drawbridge replaced a previous swing span, with a clear channel of 30’-0”, built by the Eastern Railroad in 1872. The bridge connects the Cape Ann community to the mainland. The Gloucester drawbridge is a 62’-4” single leaf three girder, double track, deck girder bascule bridge over the Annisquam River (formerly the Squam River). The main span from the main trunnions to live load shoe is 52’-4”. The west approach span over the counterweight is 27’-0” long measured from the tower bent to bearings the west abutment. The main trunnion is 21’-6” from the west abutment bearings. The west abutment is made up of a vertical masonry wall with large granite stones. The east approach span consists of eleven timber trestles spaced at 13’-0” totaling 130’-0” in length gradually fading into the Gloucester hillside. The total bridge width is 27’-0” out to out. The bridge was a hand-operated bascule bridge when first constructed in 1911. A hand crank on the side of the west approach span operated the leaf. Additional gearing and a small motor were installed at an unknown date as the primary operating mechanism, although the hand crank was retained as a backup means of operating the bridge until the machinery was replaced in the 1980s.

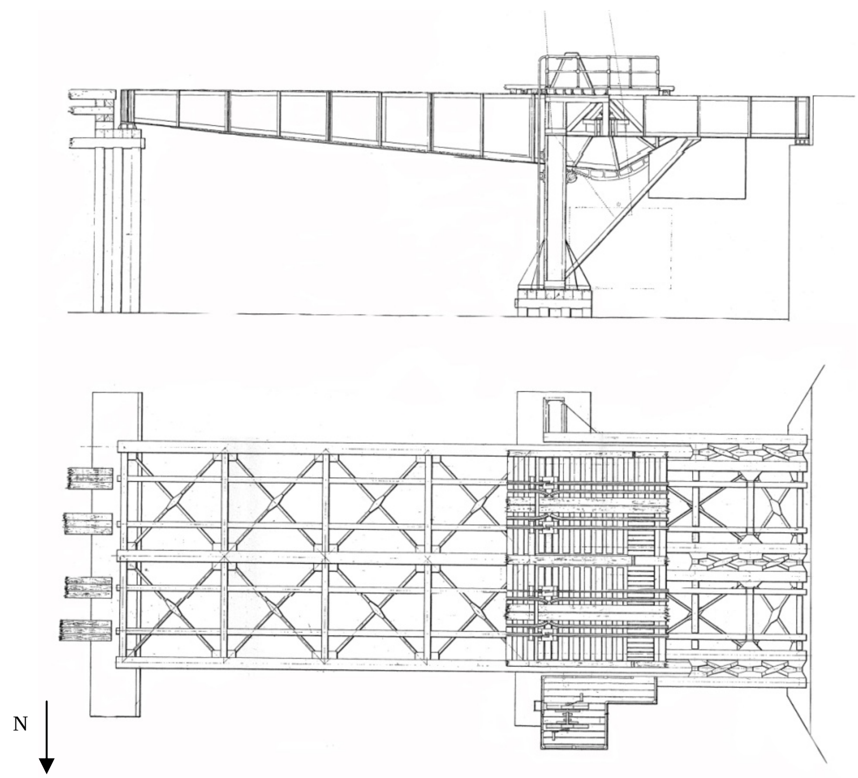

Figure 1 - General Plan & Elevation

The original operation of the span required the bridge tender to perform five tasks to open the bridge. The original tender house was located to the northwest of the span at the heel of the bridge. To initiate an opening, the tender would need to leave the house and travel a few hundred feet west to set and lock the signal red (1). After this was done the bridge tender would cross the span and continue east to set and lock the signal at the east end of the track (2). The tender then returned to the toe of the bascule leaf, turned the locking bolt to disengage the south lock and crossed to the north and released the north lock similarly (3-

4). The tender finally would re-cross the span and operate the hand-crank on the northwest end of the bridge (5). The steps were reversed to close the span. Figure 2 shows the hand operation procedure.

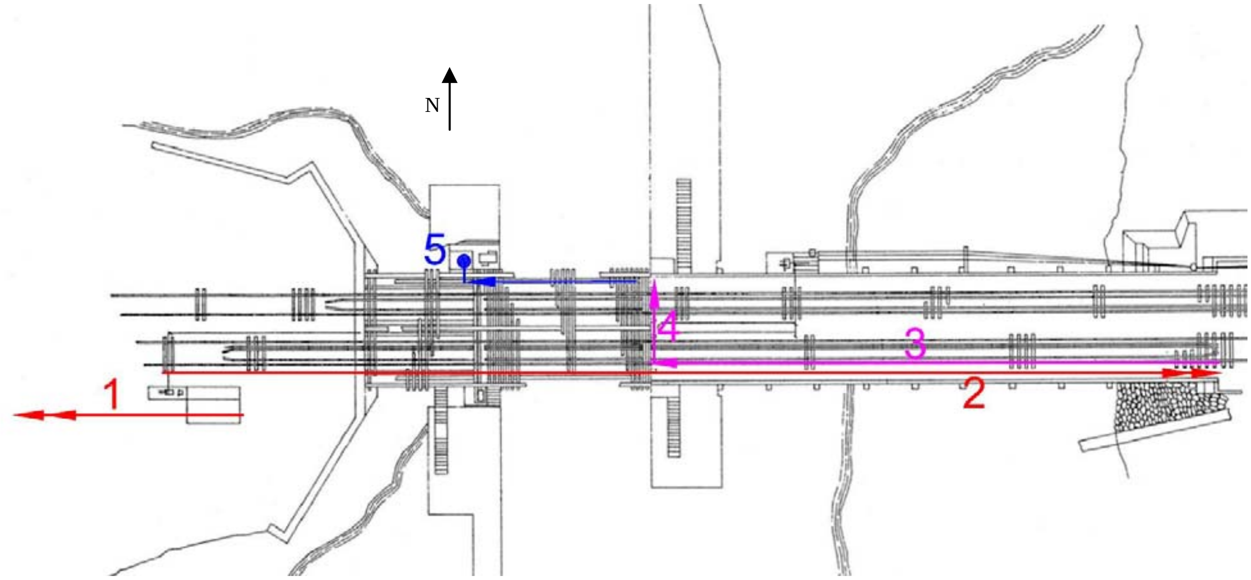

Figure 2 – Hand operation opening procedure

There are four classifications of Strauss bascule bridges. The four groups are the vertical overhead counterweight type, the underneath counterweight type, the heel trunnion type, and the direct lift type. Gloucester Draw is an underneath counterweight type bascule bridge.

The bascule leaf framing consists of three variable depth bascule plate girders, five floor beams, and track stringers under each rail. The west approach span, over the counterweight, is comprised of six-plate girders and a steel tower bent resting on a timber pier with concrete cap in the channel. The tower bent is 22’-0” tall comprised of three main built-up columns with cross bracing. The tower bent bearings rest on a timber grillage pile cap which ultimately connects to timber piles beneath. The west approach spans from the tower bent to the abutment. The bascule leaf has three forged steel main trunnions. The two outboard trunnions are 10” diameter at the outside bascule girders tapering down to 6“ at the bearings. The center trunnion is 13” diameter at the center bascule girder tapering down to 8” at the bearings. The main trunnion bearings are located on the approach girders on either side of the bascule girders. The counterweight is constructed of a steel frame and unreinforced concrete. The counterweight is suspended from the three-bascule girders with three sets of steel hangers cast into the concrete counterweight. There is one hanger on each side of the bascule girders at the tail of the girders hung from three forged steel counterweight trunnions. The two outside counterweight trunnion pins were 6” diameter at the bascule girders tapering down to 4 1/2” at the hangers. The center counterweight pin was 8” diameter at the bascule girder tapering down to 7 1/2” at the hangers. The counterweight trunnion pins are set 10’-0” back of the main trunnions on the bascule girders.

The Gloucester Bridge has a scattered history of repairs prior to the emergency counterweight trunnion pin replacement in 2011. In 1936 there were minor structural repairs to the bascule girders, floor beams, and bracing members. In 1942 there were repairs to the timber fenders and the timber trestle approach span. From 1952-1954 there were structural repairs to the steel approach span girders and steel tower bent. A major mechanical and electrical overhaul occurred in 1985. The M&E overhaul in1985 included the construction of a control house on the northwest bank, machinery platforms on the west fender, the replacement of the rack and pinion, shafts and bearings, new operating machinery, repairs to the concrete counterweight, and the addition of fire retardant on the timber trestle and fenders. In the early 2000's the timber grillage and pier was filled in with concrete.

The current owner of the structure is the Massachusetts Bay Transit Authority (MBTA). The MBTA was formed in 1964 to operate the bus, subway, commuter rail, and ferry system in and around the Boston metropolitan area. The MBTA operates the 5th most utilized commuter rail system in the United States behind the commuter rail systems in the New York and Chicago areas. The commuter rail system covers over 650 miles of track, which all either originate or terminate in the City of Boston and the MBTA is the 2nd biggest landowner in the State. The commuter rail service is typically operated and maintained by a third party contractor. At the time of the emergency repair the operator and maintainer of the bridge was the Massachusetts Bay Commuter Railroad (MBCR).

The Gloucester line is on the Eastern Route of the MBTA transit system. The main line runs north from Boston for 34.9 miles consisting of 11 stations. The Gloucester line splits from the main line at the Beverly Depot station. The line then continues east for an additional 16.8 miles consisting of 8 stations to the Rockport terminus. The Gloucester Draw Bridge is on this line between the West Gloucester Station and Gloucester Station. There are two stations on the line eastward of Gloucester Draw, the Gloucester Station and the Rockport Station.

The MBCR performed the emergency repair during a one-week track outage from Friday, June 3rd 2011 to Sunday, June 12th 2011 with the assistance of HDR. The MBCR deployed 20-25 workers per day on two-twelve hour shifts. HDR provided 24-hour project assistance to monitor the two shifts. The MBCR utilized their general maintenance workers and machinist as well as the MBTA's machinists and employed four workers from the local pile drivers union. The crew completed the repair in the allotted time frame for a total construction cost of $1,500,000. The MBTA utilized the bussing system to shuttle the MBTA riders from a designated parking area at the Gloucester Station to a station further down the line so they may still use the commuter rail service during the outage.

Emergency Design

Counterweight Pin Failure

The existing stepped counterweight pins were heavily worn and scored. Scoring at the fillet provided a site for a fatigue crack to initiate, which started on the inboard side of the northern most counterweight trunnion. Over time the crack propagated through the pin until the pin failed. After the inboard side failed the outboard side seized in its' bushing and failed bending the hanger (See Figure 3 and 4).

Figure 3 - Fatigue crack through the inboard face of the north counterweight trunnion pin

Figure 4 – Bent outboard hanger and sheared counterweight trunnion pin

Inspection & Data Gathering

The record drawings for Gloucester Draw were few in quantity and difficult to read. The drawings of the structure, main trunnions, and counterweight trunnions were in fair condition and the required information could be obtained from such drawings. The drawings became illegible once the set got to the counterweight drawings. The team did not know the size of the counterweight, how the counterweight hangers were tied into the internal framing or the strength of the concrete used to form the counterweight. The missing information was essentially all details regarding the counterweight hanger assemblies and details showing how those hangers were framed into the general steel framing of the counterweight.

The lack of this information meant the team would need to inspect the bridge to gather all the accessible measurements to help design the replacement pin hangers and determine the dimensions of the counterweight. Several trips were made to the bridge to meet with the MBCR to field measure the hangers, and check that the replacement parts would fit without interfering with existing rivet holes. Many discussions were held with the field repair team to provide a design that would be the easiest for them to fabricate and install given the tools the MBCR had available.

Jacking Design

The MBTA granted a one-week transit closure of the span to perform the repair. The design had to be simple and effective to meet the schedule. To replace the counterweight trunnion pins it was necessary to unload the pins, which meant securing the bascule span and jacking the counterweight. Since there was no enclosed counterweight pit, the counterweight location did not allow for a method to jack the counterweight from below. The unique configuration of the bridge and counterweight lead to the decision to jack the counterweight from above utilizing the approach span girders.

At the fully closed position the counterweight trunnion pins and hangers are recessed between the approach girders leaving the pins inaccessible for the repair. It was determined if the span were open to 41 degrees, the pins and hangers would be easily accessible and provide enough clearance for work crews to operate safely, comfortably, and efficiently. If the span was opened further than 41 degrees forward portion of bascule girders would interfere with the jacking system.

Figure 5 shows the jacking concept used for the project which is discussed in further detail elsewhere. The items shaded in red are the primary jacking system which includes the lifting beams, threaded rods, jacking beams, jack housings, and hollow jacks. The items shaded in light blue are the timber flange and web stiffeners for the approach girders. The items shaded in yellow are the chock beam assemblies. The items shaded in purple are the counterweight trunnion pins and hangers.

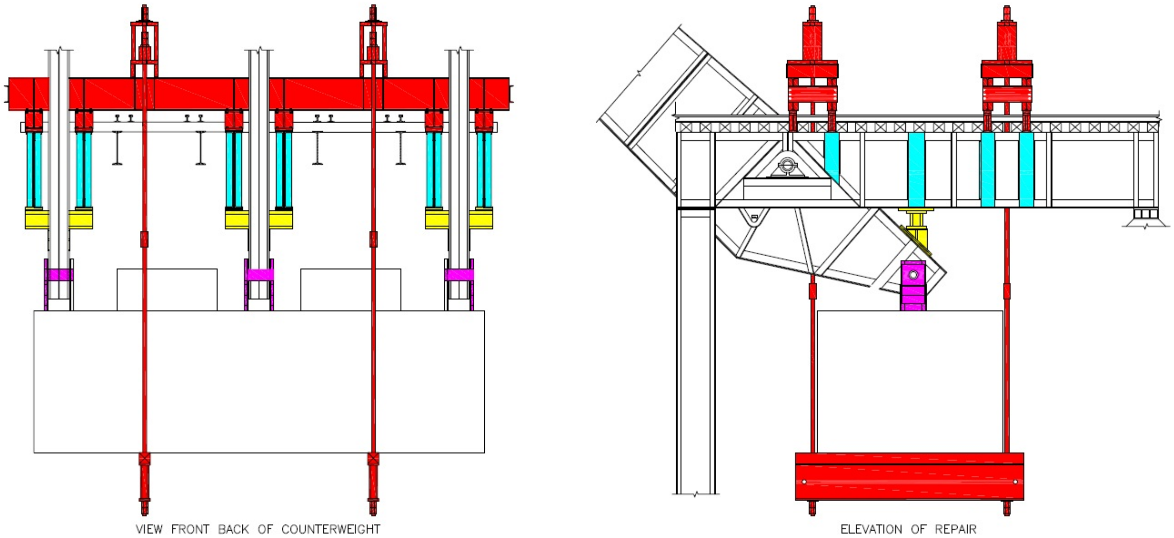

Figure 5 – Counterweight jacking scheme

The first step in jacking the counterweight was to design a system to secure the span in place, at a partially open position, while the repair could be performed. The bascule span was to be relieved of the counterweight load, causing a large imbalance tending to close the span. The concept of inserting steel chocks between the top of the bascule girders and the bottom of the approach girders was developed to keep the span in the partially open position. The chock beams would transfer the load developed from the bascule span closing moment to the approach beams above and resolve the force back to the jacks. There were three wedge shaped chocks constructed of 1" thick 50 ksi steel. The top surface of each chock was a simple horizontal surface, which would mate up with the chock beam. The bottom surface of the chock was angled to 43.8 degrees to compensate for the 2.8 degree incline of the top flange of the bascule girders and the required 41 degree angle of opening of the span. The rectangular chock beam spanned adjacent approach beams with the load applied by the chock at the midpoint between supporting girders. The total length of each chock beam was 4'-1" and was constructed of 2" thick 50 ksi steel.

With the location and arrangement of the chock system decided upon the next step was to design the counterweight jacking system. The counterweight jacking system was designed to support the counterweight by hanging the counterweight from the approach span girders.

Figure 6 – Chock beam assembly in the shop

HDR performed a Load Rating for the MBTA in 2008, which analyzed all the components of the structure influenced by the live load. The original design live load for the 1910 design utilized an equivalent Cooper E-50 loading with steam locomotive impact effects. The 2008 Load Rating rated the bridge for four loading arrangements, the Cooper E-80 car, MBTA's F40PH (280K) modified car, MBTA's 286K car, and MBTA's 263K car. The analysis of the approach span girders helped determine additional load could be taken, which allowed the design of the jacking system to jack the counterweight from above supported on the approach girders.

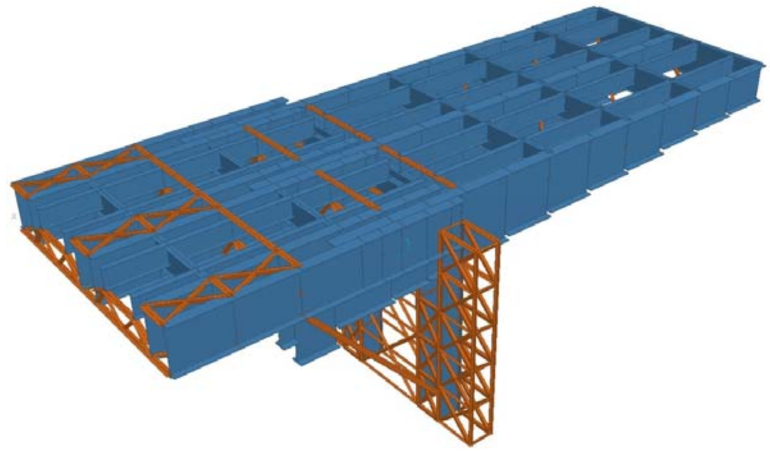

Figure 7 – Gloucester Draw STAAD model

Two pairs of W24x55 steel sections ran transversely across the approach span. The beams were designed to rest directly on the top flange of the approach girders. The jacking beam pair was spaced at 2’-4” on center. The centerline of the jacks were set 6” to 12” off the front and behind the vertical faces of the counterweight respectively to allow the room necessary for the counterweight to articulate during the jacking operation and to allow adjustment in location of the jacks. The beam pairs were prevented from racking by tying the ends together with C12x30 end diaphragms. The jacking beam pairs were placed strategically between the timber railroad ties to limit the amount of ties that would require shifting. Timber bearing stiffeners were used to brace the flanges and web of the approach girders.

Spanning across the individual jacking beam pairs was a built up housing for the jacks. The jacking seat was a two-tiered system. The first level was designed to have enough vertical clearance to place the jack, the lower jacking nut, jam nut, and the total stroke required to jack the counterweight sufficiently. The lower tier was designed to take the temporary load from the jack. The length of time for the repair required the load be removed from the jack to ensure the counterweight would not move if any of the jacks lost pressure. The top tier was designed to take the permanent load of the counterweight once the counterweight was in its final position. The upper jacking nut was designed to be tightened against the jacking seat to lock the counterweight at each incremental lift point until the counterweight was sufficiently jacked and to support the counterweight during the replacement. Four jacks and jacking seat assemblies were utilized in the design.

Figure 8 – Jacking seats in the shop

Each jacking seat was comprised of two 10x20 channel sections. On top of the two channels were the jack bolsters made up of 2 1/2” 50 ksi steel plate.

Threaded rod was chosen to lift the counterweight. The original design called for the use of 2 1/4”diameter 75 ksi Dywidag bars. After a few attempts to acquire the required number of bars and lengths it was found that they could not be procured in the time frame required to meet the MBTA schedule. An alternative bar type was chosen from the Williams Company. Williams typically supplies high-strength bars for the post/pre tensioning concrete industry. The high capacity and easy procurement of the bar sizes, strengths, and lengths required lent itself well to the emergency jacking application required.

Figure 9 – Lifting beams in staging area on site

The threaded rod passed through the jacking seat and jack, between the approach span framing and bracing, and down below the counterweight to the counterweight-lifting beam. Two lifting beams were designed to lift the counterweight from below the counterweight. The lifting beam would be pulled up against the counterweight, picking up the counterweight in the process. The shape of each beam was a slender rectangular box section. The ends were left open for access. The top and bottom flanges were slotted with 9” long oversized slotted holes for the threaded rods to pass through. The slotted holes allowed for field adjustments. Timber was placed on the top flange of the lifting beams to bear against the bottom of the counterweight. The bottom of the counterweight was slightly irregular and of questionable integrity. The sacrificial timber was utilized to essentially crush under the jacking load, deform to the contours of the counterweight, and then finally provide a uniform surface for the lifting beam to bear against the bottom of the counterweight. An assumed concrete compressive strength of 2,500 psi was used to determine the required bearing area on the concrete since the actual strength was unknown.

The lifting beams were built-up rectangular box sections with a total depth of 2’-2”. The flange plates were 1” x 8” top and bottom, and overhung the edge of the web sections slightly. The two web plates were 1” x 24” spaced 6” apart. The flange plates and web plates were welded together at the slight overhang with continuous fillet welds. (See Figure 9)

Counterweight Trunnion and Hanger Bearing Design

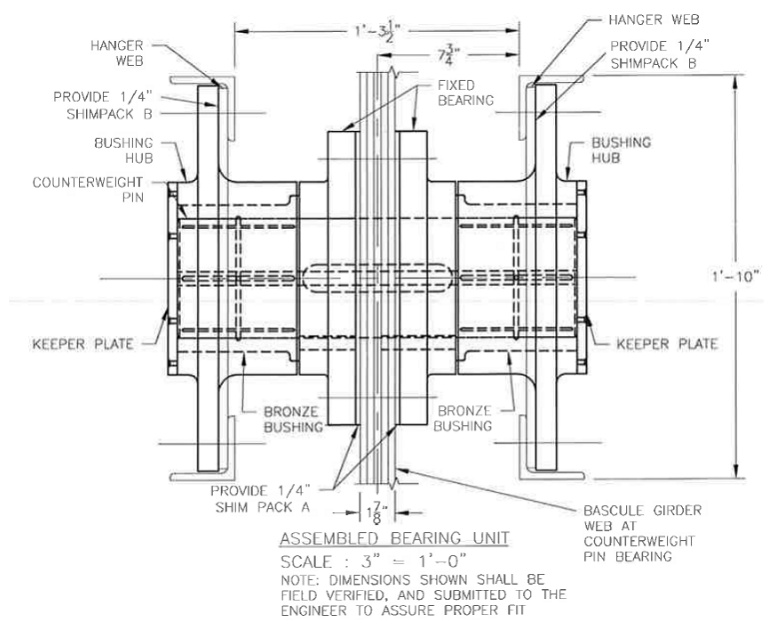

Figure 10 – Section of the assembled counterweight trunnion

The original counterweight trunnions were found to be slightly undersized per the current AREMA specifications and the hanger bearing bushings were overloaded. It also became evident that there was likely load sharing which was not ideal. With a three-girder design the center bearing should take a little over 60% of the load, based on a 2-span continuous beam model, and the outboard bearing would share the remaining load. It is difficult to have ideal load sharing on the counterweight trunnions, and ensuring this condition requires careful alignment. Considering that the existing alignment and loading was suspect, the team decided to make all the counterweight trunnions the same. Because the bearing loads are very high, and the space for shafting limited, an 85 ksi, 6 1/2” diameter, counterweight trunnion was specified with UNS C95400 35 ksi bronze bushings. By using a constant diameter trunnion, the shoulders were removed from the shaft design to reduce stress concentrations and the shaft is retained by keeper plates attached to the ends of the bearings. Figure 10 shows the design drawings of the assembled bearing through the bascule web looking down at the top of the counterweight. Figure 11 shows the assembled bearing in the shop.

It was determined that the counterweight hangers could be cut off to provide improved access to remove the original counterweight trunnions. New hangers were designed to be spliced to the remaining steel above the counterweight top. The locations of the rivet holes were determined in the field and the design ensured that all available rivet holes were used and that no rivets were located along a splice.

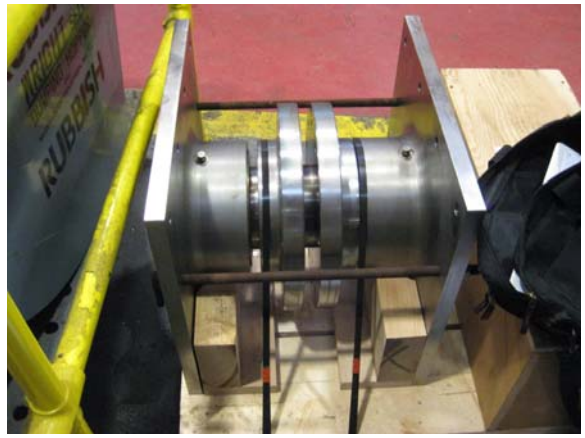

Figure 11 – Assembled counterweight trunnion in the shop

Emergency Repair

Site Preparations

Site preparations by the MBCR were essential to be able to perform the work in the allotted track outage without incurring financial penalties. To expedite the construction time the MBCR team created a wooden mock-up of the chock and chock beam. The MBCR fit the mock-up in the prescribed locations dictated in the design to identify any possible issues during the repair. The MBCR identified exact locations of existing rivets that could be removed and replaced with H.S. bolts in the bascule girders and approach girders prior to the outage. They also were able to determine additional interferences not discernible from the original drawing set. The MBCR removed and replaced existing rivets in the top flange of the bascule girders and bottom flange of the approach girders where the chock and chock beam would need to be installed. There were also rivets removed and replaced with H.S. bolts on the top flange of the approach girders where the jacking beam pairs were to sit.

Figure 12 – Mock up chock assembly in the field

Typical access to the hanging counterweight was limited and troublesome if the team intended to move workers on and off the top of the counterweight safely and efficiently. The MBTA and MBCR decided to build a permanent platform below the counterweight for the rehabilitation project. 2” open fiberglass grating was placed on new timber framing. The framing was secured to the west abutment and the central pile cap. The new platform allowed for safe access to and from the counterweight and also gave the team a location to build scaffolding in order to access the counterweight pins and hangers on the north side of the north hanger and south side of the south hanger.

Installation of the Jacking System

Work to repair the broken counterweight trunnion pin commenced Friday, June 3rd 2011. The track outage began that night at 9 p.m. so that the process of jacking the counterweight could begin. The MBCR would supply the labor required to perform the full replacement project and run the project 24 hours a day in two primary shifts.

To begin the project the team awaited for the arrival of the rigging crew with the rail mounted crane. The crew arrived around midnight and began to remove the rails on the approach span. The crew cut the rails and stored the removed rails on the side of the job site for the duration of the project. Once the rails were removed the timber ties were slid out of the way to make space for the jacking beams (See Figure 13). This concluded Day 1.

Figure 13 – Opening in the approach span to access the top of the counterweight

On Day 2 the team prepared the bridge for installation of the chock assemblies. The bridge was opened to the approximate angle the plans designated and the brakes applied (See Figure 14). The crew could access the counterweight once the span was partially opened. The ties above the counterweight were shifted to allow for direct access down to the counterweight. Through this access the crew could lower down the chock assemblies and replacement pins before the access was occupied by the jacking system.

Figure 14 – Bridge halfway open with the brakes applied

The bolts were removed from the bottom of the approach span girders and top flange of the bascule girders to receive the chock assemblies (See Figure 15). The outboard approach girders each had angle struts that connected from the bottom flange of the girders to the base of the towers. The existing struts were to be temporarily removed for the project since they would interfere with the installation of the chock beam assemblies. Upon removal of the northern strut at the approach span flange of the connection it was uncovered the bottom flange was about 80% rusted out. The flange of this approach girder had to be repaired in the field so that the chock beam would bear on the bottom flange properly. Once the struts were removed and flange repaired, the chock installation could proceed.

The crew first moved the center chock into place. The chock was lowered through the opening in the ties over the counterweight. Prior to the outage the crew marked on the top of the bascule girders where the chocks were to be placed. The center chock was then roughly placed in the predefined location. The connections of the chock assemblies to the girders were designed to reuse the bolt locations on the girders that they bear against. It became evident in the field the number of required bolts to connect the chock assemblies were not available on the center bascule girder. In lieu of bolting, the crew field welded a 5/16” fillet along the width of the flange and chock (See Figure 15).

Figure 15 – Chock assembly engaging the bascule girder and approach

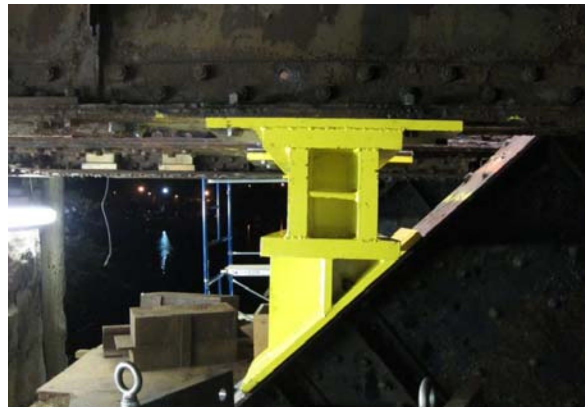

Figure 16 – Chock assembly engaging the bascule girder and approach girders

The same procedure was followed when installing the chock assemblies for the two outside bascule girders. The method of securing the chocks to the bascule girder by fillet weld became the preferred method for all three-chock assemblies. The time saved by securing the chocks in such a manner would be lost later when removing the welds during the de-jacking process. The chock assemblies were only securely fastened to the top of the bascule girders. The connection interface at the bottom of the approach girders was much more forgiving than the bascule girders. The chocks were bolted to the bottom flange of the approach girders, reusing the existing bolt holes.

Once all three chocks were securely in place the crew staged the three replacement pin assemblies below the deck on the counterweight while the access above was still open (See Figure 17).

Figure 17 – Bearing assemblies being lowered to the counterweight

The next step was to install the jacking beams. The jacking beam pairs were installed transversely across the top of the approach girders. Each beam location was already marked off with its rivets removed. The crew placed each jacking beam in the required locations and bolted each beam to the top of each of the six the approach girders (See Figure 18). The beams were installed on the top flange of the approach girders and shimmed. The end diaphragms for each beam pair were installed after each beam pair was set.

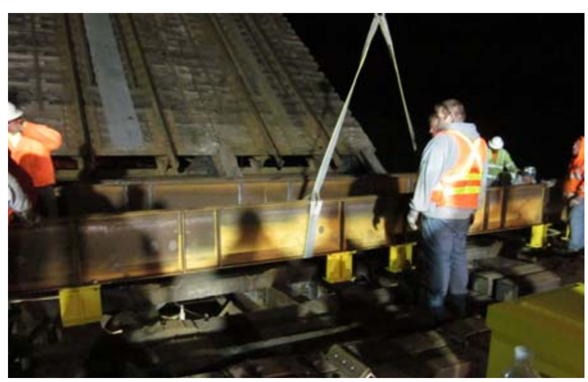

Figure 18 – Jacking beams being lowered onto the approach girders

As Day 3 began, all the jacking beams were installed on top of the approach span girders; the crew began to stage the lifting beams below the counterweight on the platform. The next step was installation of the jacking seats. The jacking seats were set across each beam of the jacking beam pair (See Figure 19). There were four jacking seats to be installed. The location of jack seats had to be set so that the threaded rod could be passed through the jacks, bridge framing, around the edge of the counterweight, and through the lifting beam slotted holes. The jacking seats were shimmed to have a level jacking surface for the jacks.

Once the jacking seats were in place the crew began to move the lifting beams into position under the counterweight (See Figure 20). The underside of the counterweight was irregular thus a timber bearing beams were placed between the lifting beam and counterweight. The lifting beams were lightly jacked against the bottom of the counterweight to await placement of the threaded rods.

Figure 19 – Jacking seat being installed

The threaded rods were installed after the lifting beams were moved close to their final position. Each threaded rod was 16’-0” long. There were two thread rods used at each jack. The thread rods were coupled together with threaded couplings just above the counterweight. After installation of the threaded rods the lifting beams and jack seats could be set to their final locations and the final preparations prior to jacking could begin. (See Figures 20 and 21)

Figure 20 – Lifting beams being installed under the counterweight

Final preparations for the jacking later that night included construction of a wooden walkway for safe passage of the crew around the jacking beams, torquing any bolts that were removed to facilitate the installation of the jacking system in the approach girders and bascule girders, and finally to engage the timber flange and web stiffeners to bear against the flanges of the approach girders and bascule girders. To engage the timber stiffeners the crew utilized timber wedges driven by hand.

The jacks were connected to a single hydraulic manifold with four outputs, one for each jack. The jacks and manifold outputs were color coated to help identify which valves from the pump controlled which jack. The jack system would allow each corner of the counterweight to be controlled for minor adjustments. A dial indicator was set up on each bascule girder to measure the relative movement of the counterweight bearings to the bascule girder.

Figure 21 – Installation of the threaded rods

The crew began jacking the span around midnight of Day 3 going into Day 4. The counterweight was jacked one corner at a time at 1/4” increments. Once the jacking began, the looseness and flexibility of the structure was tightened up as the counterweight load was being removed from the bascule girder and the chocks began to take the load. As the counterweight load was removed from the bascule girder, the bascule span was almost entirely span heavy. The pressure exerted by this imbalance was passed through the chocks to the chock beams and through the approach girders. It quickly became evident that the dial indicators were unable to provide any useful information due to the flexibility of the structure and racking of the structure from the failed counterweight trunnion. One of the indicators showed the counterweight was lifted 0.2” without any clearance developing in the bearings.

Due to the failed pin on the north side of the counterweight the counterweight was tilted. The total lift of each jacked varied because of this and ranged from 1 7/8” to 2 1/2” (See Figure 23). The completion of jacking was determined by inserting a feeler gauge around the counterweight trunnion pin and steel hub at the hangers. It was an iterative process of adjusting the jacks at each corner to get this condition at each of the trunnion pins. As the crew lifted one side of the counterweight, the opposite side of the counterweight would lower since the counterweight pivoted about the lifting beams, which were inboard of the outboard hanger bearings. The north side of the counterweight at the failed pin side had sagged significantly and was lifted to be as level as possible with the south side; the counterweight was lifted until the center and south pins just touched to top of their bushings.

Figure 22 – Complete jacking assembly

Figure 23 – Hollow Jack after jacking

Removal of Existing Counterweight Trunnions & Installation of the Replacement Trunnions

Removal of the existing counterweight trunnions required the removal of the existing hanger bearings to gain access to the web of the bascule girders. The fits of the pin hubs and turned bolts were unknown prior to disassembly of bearings so the team was prepared with various methods to remove the pins. Fortunately, the fits were not too tight. The turned bolts were driven out, several of the hubs were flame cut, and the pins were pressed out with a 20 ton jack against the recess in the counterweight. The center hubs had a bolt pattern to match the original bolts drilled and reamed to 7/8”. The outboard bearings had a bolt pattern which was larger than the original bolt pattern. The

Figure 24 – The center counterweight trunnion bushings were cracked and had excessive clearances

MBCR used a machined template that had holes which matched the original bolt pattern to ensure that the new holes were concentric with the originals. Although there were some doubt this could be done with the accuraracy required for turned bolts the method proved successful and all hub bolts were installed without any issues.

The counterweight pin replacement was desperately needed; after the north counterweight trunnion failed the center trunnion was forced to carry nearly the entire load of the counterweight. The bushings on this center bearing were cracked and had large clearances and three of the six turned bolts had sheared.

Figure 25 – Bolt template being used to drill the new bolt pattern into bascule girders

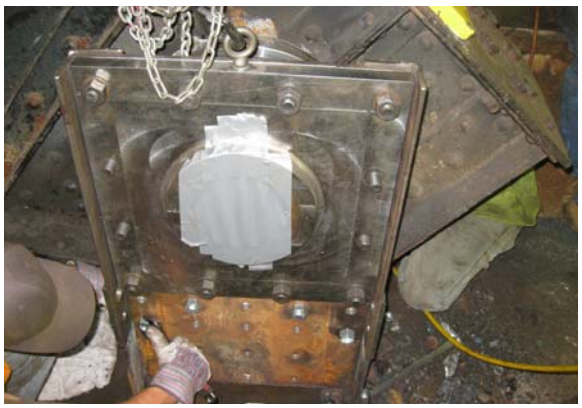

Figure 26 – Hanger assembly being splice into existing cast-in hangers

De-Jacking & Troubleshooting

Once the third and final counterweight trunnion pin was installed the dismantling of the jacking structure began. The total dismantling of the jacking system took roughly 14 hours from 11:00 p.m. Thursday night to 1:00 p.m. Friday afternoon. The load of the counterweight was de-jacked by relieving load on the threaded rods with the hollow jacks then loosening the nuts and lowering the jacks until the new counterweight trunnions were carrying the entire load. The bolts which connected the chock beam to the approach span girders were removed. After the bolts were removed the bridge was operated to open the bridge slightly to relieve any loads on the chock assemblies. At this point the entire load of the counterweight was on the new counterweight trunnion pins. The rest of the jacking system was removed in reverse order of installation and loaded to an awaiting flatcar. The most time consuming portion of the removal of the jacking system was the grinding of the 5/16” fillet welds at the chock on the bascule girder. Each chock beam took just over an hour to grind out the welds without damaging the bascule girders.

Troubleshooting began once all the jacking equipment was removed. The troubleshooting essentially consisted of modifying the approach span girder bottom flanges and the counterweight trunnion pin hangers. The original hangers and approach span girders were modified to allow for the hangers to pass up-and-in between the bascule girders and the approach girders. The new hangers that were spliced to the existing hangers were straight, uncut, steel angle. The bridge was raised in small increments until the potential interferences could be identified and addressed. The approach span girders and new hangers were notched out to fit at all three pin locations.

Figure 27 – Modifications to the approach span girders

Conclusion

Many challenges were encountered during the repair because of the one week time frame allowed and the tight working conditions under the approach span on top of the counterweight. Careful planning and preparation was key to reducing the number of problems encountered, however, jacking, installing the chocks, splicing the hangers, and realigning and installing the new counterweight trunnion pins presented unique challenges which could not be planned for. Close teamwork between HDR, the MBCR, the MBTA, and the ability of the installation team to adapt to field changes was key to the successful replacement of the counterweight trunnions. The bridge was re-opened to rail traffic on schedule.

Figure 28 – Completed installation of counterweight trunnion pin