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Performance/Construction/Maintenance

Reconstruction of the Martin Luther King Jr. Memorial Bridge over the Maumee River - Toledo, Ohio - Planning, Design and Construction Considerations

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Abstract

The Martin Luther King Jr. Memorial Bridge over the Maumee River in Toledo Ohio was completed in 1914 by C. H. Fath and Son Construction, National Foundation and Engineering Co, and Toledo Bridge and Crane Company. Due to the age of the existing bridge and load capacity limitations, the City of Toledo decided to replace the existing rolling bascule span. In 2001, the City of Toledo contracted with HNTB to provide engineering design services associated with the planning and design for rehabilitation of the arch spans and a new movable span.

Maintaining navigation clearances, and reusing the existing pier with a wider roadway, caused space constraints that affected track locations, girder depths, rack configuration, and machinery size, location and access. This paper presents the challenges and resolutions in designing the wider rolling bascule span and reusing the existing pier, with minimum navigation interruption while also maintaining roadway traffic.

Introduction

History

The closed spandrel, earth-filled arch spans with a double leaf Scherzer type rolling bascule was originally known as the Cherry Street Bridge across the Maumee River in Toledo, Ohio. This bridge was designed by Mr. Wilbur Watson of Osborn Engineering Company in 1905 as a trunnion bascule, but was modified to a Scherzer rolling bascule by Mr. Ralph Modjeski prior to construction. The original bridge provided for two lanes of vehicular traffic and double tracks for a trolley system. Prior to the reconstruction, scheduled to be completed in 2006, the bridge provides for 5 traffic lanes in a 52 foot roadway and two 9 foot sidewalks. One interesting aspect of the original construction is that the entire bridge was constructed in two longitudinal halves. This proved beneficial for the reconstruction. A postcard photo of the original bridge is shown in Figure 1. Originally the control houses were to be constructed as very tall towers that would "light up the river" for navigation, but due to funding constraints the towers were not added and the temporary houses shown in the postcard were constructed. The existing houses on the structure were constructed sometime prior to the 1940's.

Figure 1 – Postcard of Original Cherry Street Bridge

To the benefit of the reconstruction project, the bridge's bascule and arch spans were originally constructed part-width. The arch spans were constructed with longitudinal walls that retained the earth fill so that construction could be performed one half at a time. The drive machinery was configured to operate one half bascule leaf at the start and once completed a full leaf. A gear set operated as a pinion/gear pair for one half leaf and then was reconfigured on the shaft to form a differential gear set that operated the entire leaf. The centerline differential is shown in Figure 2. With the half leaf operation, the pinion and differential ring gear were in the position of the differential bevel gear on the left. Once the leaf on the right was placed, the shaft was connected, the differential was assembled, and the pinion placed at the centerline to operate the entire leaf. Floor beams were also placed between the two longitudinal leaf sections to form one leaf.

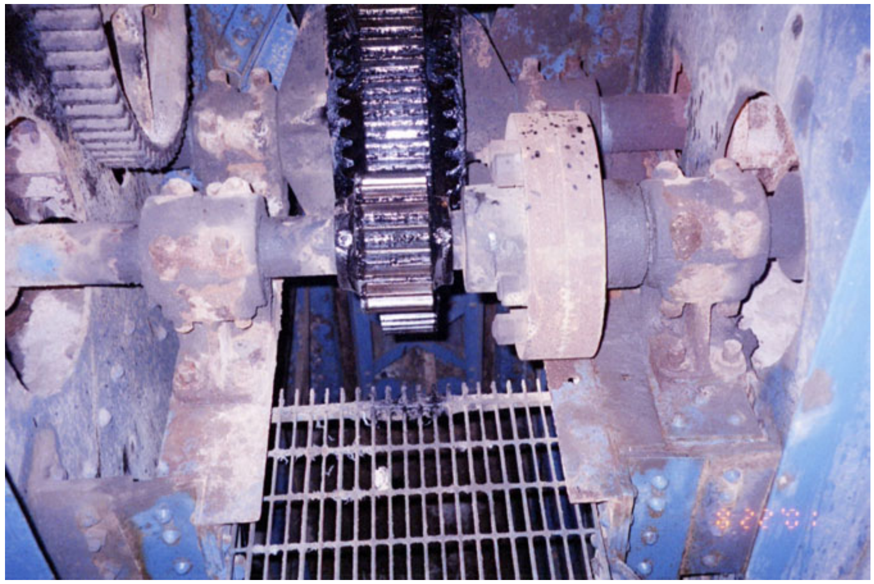

Figure 2 - Center Differential

Another interesting aspect of the original machinery is that the rack pinion was placed forward of the center of roll. This enabled the girder bearing stiffeners at the center of roll to continue uninterrupted from girder bottom flange to girder top flange. This resulted in a rack that was cycloidal in shape instead of a straight rack.

Reconstruction Criteria

Historical Preservation

The bridge is not listed on the National Register of Historic Places, but the state of Ohio historic preservation office requires the new bascule span, control towers, and pier modifications to closely match the existing structure. This means the lines and features of the movable span, control houses, arch spans, and railings, have to be duplicated if replaced. In addition, an open-air Maritime Museum placed under the concrete beam span is to be rehabilitated.

Navigation

The reconstructed bascule span has to maintain the same vertical and horizontal clearances for navigation, and the profile of the bascule girders can not encroach on the existing navigation clearances. Several Great Lake shippers use the channel and operate all year around and the reconstruction of the bascule span is staged to minimize the required channel closing time. The full channel closure is scheduled for 10 weeks in the winter of 2006 as agreed to by the USCG.

Vehicular and Pedestrian Traffic

The bridge is a fundamental link between the downtown business district and entertainment businesses on the east bank of the river. While vehicular traffic can be detoured to other bridges, this disturbance to downtown access is undesirable to the City of Toledo. In addition, the amount of pedestrian traffic on the bridge is very high and emergency facilities are not located on both sides of the Maumee River. For these reasons the City requires that two vehicular lanes and one sidewalk be maintained throughout the reconstruction project.

Roadway

The City of Toledo wanted to widen the roadway across the arch spans and bascule span to standard lane widths. This results in a wider structure width that includes 5 traffic lanes in a 64 foot roadway and two 8 foot sidewalks. The arch spans and bascule span are designed for an HS 25 loading as well as a special "Michigan Truck" load. A crash tested barrier spans the length of the bridge. On the approach spans, the decorative concrete railing also serves as a crash tested barrier. However for the bascule span a crash tested barrier will separate the roadway and sidewalk so the pipe handrail could be replaced in kind for historic reasons. The new bascule span incorporates a concrete filled grid deck to protect the steel members below from the corrosive road salt that deteriorated the original structure.

Project Plan

In order to limit the disruption to navigation, vehicular, and pedestrian traffic, and to satisfy funding requirements, the reconstruction project is performed in two phases. The first phase will only be briefly discussed in this paper, with more detail presented on planning the second phase.

Filled Arch and Concrete Beam Span Reconstruction (Phase 1)

This phase consists of repair and widening of the arch spans; replacement of the west abutment and concrete girder spans; and replacement of the sidewalks and barrier railing. New sidewalks and barriers are cantilevered from the edge of the arch as shown in Figure 3. The new wider roadway results in an increase in the dead load of the bridge on the substructure. In order to offset the increased roadway loads, the arch span fill is removed as shown in Figure 4 and replaced by a lighter engineered fill. The reconstruction is accomplished part width to maintain vehicular and pedestrian traffic. The bridge after the completion of Phase 1 is shown in Figure 5.

Figure 3 - Arch Span Sidewalk Construction

Figure 4 - Arch Spans without Fill

Figure 5 – Completion of Phase 1

Bascule Span Reconstruction (Phase 2)

This phase is planned for 2004 through 2006 and consists of rehabilitation of bascule piers, new control houses, placement of new track supports, new rack supports, new bascule span, new machinery, new electrical control system, new electrical drives, and new access to machinery. Since a trunnion bascule span was planned for the original bridge in 1905, a trunnion bascule was considered for the reconstruction. This span type was abandoned since it could not provide the same horizontal navigational clearance for the existing pier and counterweight size that a rolling bascule span could provide.

Control Houses

The current control houses are constructed of concrete and because of their location would hinder the movement of a wider rolling bascule span. New control houses are erected on the opposing corners from the current houses prior to the bascule span change-out as shown in Figure 6. The existing houses are shown with a blue roof, and the proposed control houses are shown with a copper roof. The new houses look similar to the existing octagonal control houses, but are constructed of pre-cast concrete wall panels supported by a steel structure. The roof is a standing seam copper roof similar in appearance to the existing house roof. The installation of the electrical control system in the houses occurs prior to the span change-out. Lightning protection is also provided.

Figure 6 - Control House Construction

Construction Sequence

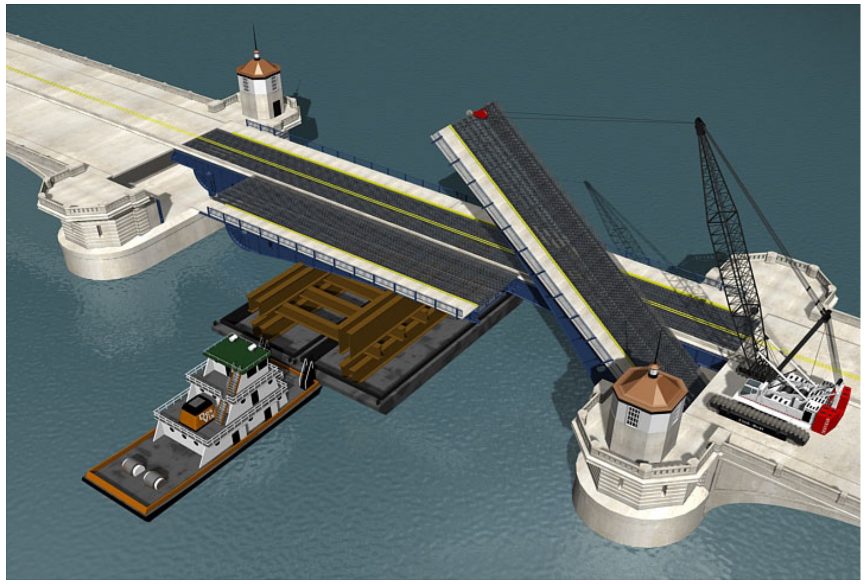

Figure 7 - Leaf Removal

To perform the work in the allotted time for the channel closure and to maintain vehicular and pedestrian traffic, the bascule span is floated in as four preassembled bascule leaves. The contractor is to remove a quadrant leaf as shown in Figure 7, install the new track supports, rehabilitate the pier, install a new rack support and place a new pre-assembled leaf that contains the machinery and electrical components already installed. This process is repeated for the other leaves. Adjacent leaf pairs are mechanically and structurally tied together to form a single leaf. The control system does not allow operation of half leaves, so machinery operation is not performed until the leaf pairs are tied together.

Substructure

The existing bascule piers consist of non-reinforced concrete with large layers and/or pieces of sandstone found throughout the depth. The bascule piers are supported on concrete caissons founded in bedrock. During the original construction of the piers, a thick mud sill was used to facilitate pier construction in the Maumee River.

Due to the limited reconstruction timeframes, replacement of the piers or widening of the piers was not a feasible option. For this reason the existing bascule piers were evaluated for adequacy with the wider, heavier superstructure, and heavier vehicular loads proposed. Based on geotechnical recommendations, the existing bascule piers are adequate for the new loads.

The existing bascule span is supported by the track frame. Pintles on the track frame guide the rolling girders along the track as the span is opened. The existing frame consists of a heavy steel girder supported in the front by the pier wall and a steel column in the rear as shown in Figure 8. The entire frame is encased in concrete for added strength. The track frames supporting the new bascule span are similar in design to the original; however, the track girder is supported in the front and rear by a steel column founded on solid concrete in the pit as shown in Figure 9. This self-supporting frame is used because structural integrity of the front pier wall could not be adequately confirmed for the new loads and because it minimally disturbed the front pier wall during construction. It is important to maintain the integrity of the front pier wall because half of the bridge is in use during reconstruction. As with the original design, the track frame is encased in concrete for added strength.

In addition to the track frame, live load anchors, located behind the roadway break, hold the tail of the bascule span down and keep the span from over-rotating. When the bascule span is balanced, these anchors are only engaged when a vehicle is on the bridge in front of the center of roll. The existing live load anchors are secured to the bascule pier with long tie rods attached to large steel grillages located below the pit floor. Due to the higher vehicular loads on the bridge, increased weight of the new span, and deterioration of the existing anchors and rods, the existing tie rods are inadequate for the new span. For this reason, new live load anchors are installed during Phase 2 of the reconstruction. As with the original design, tie rods are used to secure the live load anchors deep into the existing bascule pier. The new tie rods are high-strength all-thread rods. After installation the live load anchors are post-tensioned to the bascule pier since attachment to a grillage deep within the pier was not feasible. The addition of new live load anchors allows the bascule span to receive full design loads without the counterweight in place.

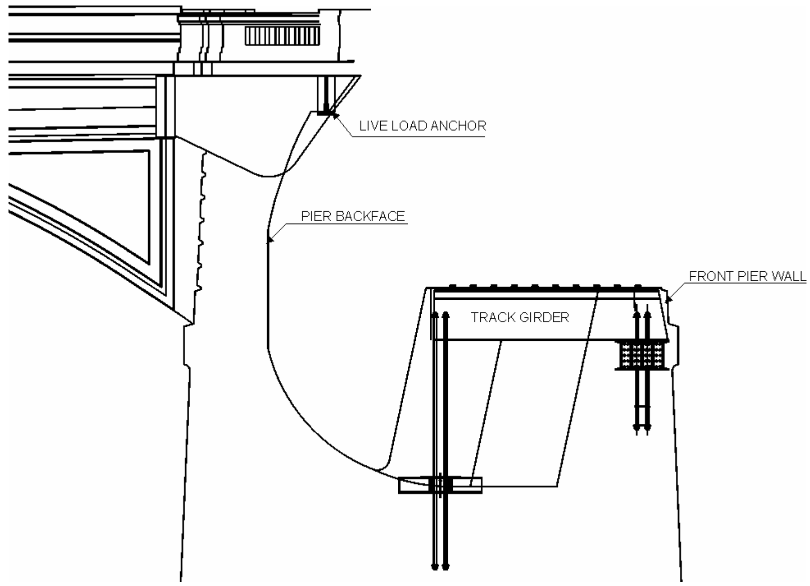

Figure 8 - Existing Track Girder - Section through Bascule Pier

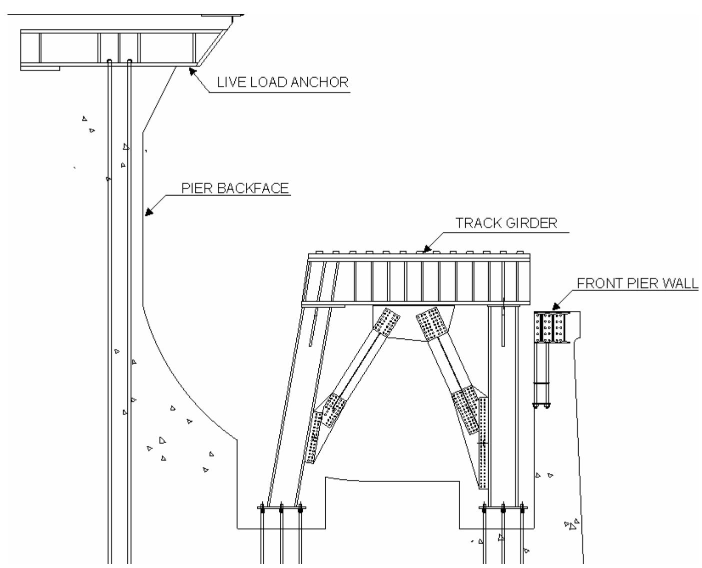

Figure 9 - Proposed Track Girder - Section through Bascule Pier

Superstructure

The original bascule span consists of four main girders per leaf, with an open grid deck supported on a floorbeam-stringer system. Since the reconstruction requires two lanes of vehicular traffic to remain open at all times, the bascule span is replaced in longitudinal halves. Due to this requirement, the new bascule span also has four main girders per leaf so two girders can adequately support two lanes of traffic and a sidewalk. The new main girders are re-spaced due to the wider roadway deck and navigation closure window. The short navigation window requires all substructure elements to be in place prior to the channel closure.

Unlike the existing span, the new bascule span has a filled grid deck with concrete overlay which reduces the corrosive effects of salt treatment on the girders and main supports. The deck is supported by a floorbeam-stringer system similar to the original span. The sidewalk is separated from the roadway with a crash tested barrier. The original span has a minimal barrier that is not crash tested. The handrail on the new span is similar in style to the existing.

Another key difference between the original span and the new bascule span is the reduction in the roll radius. Because it was desired to move the main reaction in the closed position away from the front pier wall, the center of roll was moved back toward the roadway break. The backface of the pier could not be moved back or adjusted due to the adjacent arch spans; therefore, the roll radius of the new girders decreased.

Counterweight

Design of the counterweight was challenged by space restraints and load requirements. Since the adjacent arch spans are cast integral with the bascule pier, the profile of the backface of the pit can not be modified significantly. The new counterweight must be located behind the new center of roll location and in front of the existing curved backface. This forces the new counterweight to be physically smaller than the original counterweight while balancing a heavier span.

The filled grid deck adds a substantial amount of weight to the span, pushing the span center of gravity toward the leaf tip, and results in large steel blocks being embedded in the top of the counterweight to compensate. These large steel blocks consist of laminated plate and each block is approximately 8’-4”H x 4’-0”W x 2’-0”L in size. The laminated plates raise the counterweight center of gravity so the line of influence between the span and counterweight center of gravities passes through the center of roll. Forcing the center of gravities to pass through the center of roll ensures the span is balanced at all angles of opening.

Machinery

Available space constraints also had a significant effect on the size and orientation of the drive machinery. The reduction in roll radius decreases the mechanical reduction from the span and requires more reduction from the enclosed gear drive reducer. Limited vertical clearance above the racks did not allow the rack to be above the pinion. This again decreases the reduction available from the roll radius and increases the reduction requirements of the reducer. The orientation of the machinery accommodates a larger counterweight. The machinery is flipped about the center of roll so that the machinery enclosure is now over the channel. Now as the leaf rolls open the high speed shaft of the reducer rotates over the low speed shaft. Lubrication of the high speed shaft bearings is a concern, and the reducers now require lubrication pumps.

Access

Access to the mechanical components for maintenance is a challenge due to space constraints from a wider roadway and larger counterweight in the existing pier. Normal access to the machinery enclosure on a rolling bascule is accomplished through a door in the girder. Since the pinion lies at the forward pier wall, a door forward of the pinion could not be accessed and a door aft of the pinion interfered with the counterweight. The machinery enclosure is accessed by climbing through the rack frame around the girder tread and up through a hatch in the machinery floor. The enclosure is accessible when the span is in the up position. This is similar to current machinery access on the existing span.

Access in the control house is also affected by the wider roadway. The control houses need to be moved away from the centerline of the roadway and could not be made larger. One floor of the control house does not have the space available for a standard stair case and is accessed by alternating tread stairs. In the existing house this floor is accessed by a ladder.

Summary

Meeting all of the project requirements and construction constraints was a challenge for this project. Special consideration was given to construction sequencing while maintaining the historical appearance of the Martin Luther King, Jr. Bridge.

During Phase 1 reconstruction, the wider roadway deck proved challenging. With the replacement of the earth fill in the arch spans with a lighter weight material, the existing substructure elements were reused without strengthening. The longitudinal arch ribs used to originally to construct the bridge were beneficial in maintaining vehicular traffic on the bridge during this phase of reconstruction.

The Phase 2 reconstruction was also challenging due to the combination of a short navigation closure window while vehicular traffic still uses the bridge. By keeping these requirements in mind during the entire design process, the bascule span can be constructed in quadrants with minimal field work at the bridge site. This construction sequence greatly reduces the amount of time the span is fixed in the closed position and allows vehicular traffic to use the bridge during span change-out.

Both phases of the reconstruction had challenging aspects which affected the design and construction sequencing decisions made. In the end, the City of Toledo will get a new bridge while meeting all of their navigation and vehicular needs.