Assembly and Erection of
Pamunkey River Bridge Bascule Span

1. INTRODUCTION

This paper discusses the assembly and erection of the structural steel and machinery for the bascule portion of the Pamunkey River Bridge in West Point, Virginia. This work is part of a one mile long, four-lane bridge replacement under construction for the Virginia Department of Transportation. Work on this $89m contract began in late 2004, and as of September 2006 the project is 70% complete. The projected completion date of October 2007 includes demolition of the existing two-lane bridge, which incorporates a low level swing span.

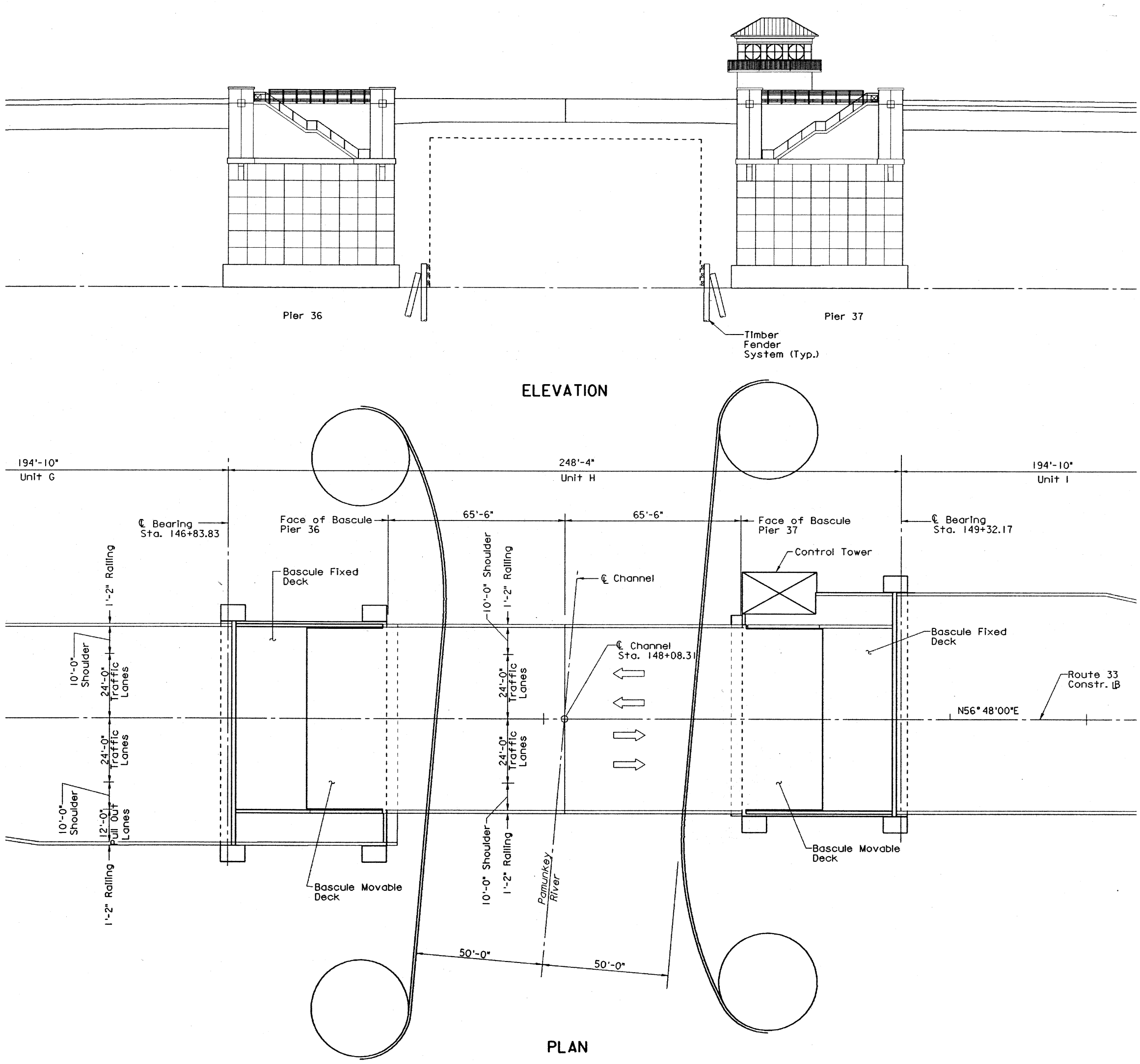

Figure 1 – Plan and Elevation of Bascule Span

2. PROJECT BACKGROUND AND DESIGN FEATURES

This double-leaf trunnion bascule spans 173’ (trunnion to trunnion) with a vertical channel clearance of 55’, as outlined in Figure 1. Due to the bridge’s clearance, no regular openings for marine traffic were anticipated, only bi-weekly maintenance openings which the owner acknowledged might occur at less frequent intervals. Therefore, redundancy and reliability were the main criteria for the designers. These factors resulted in the following features:

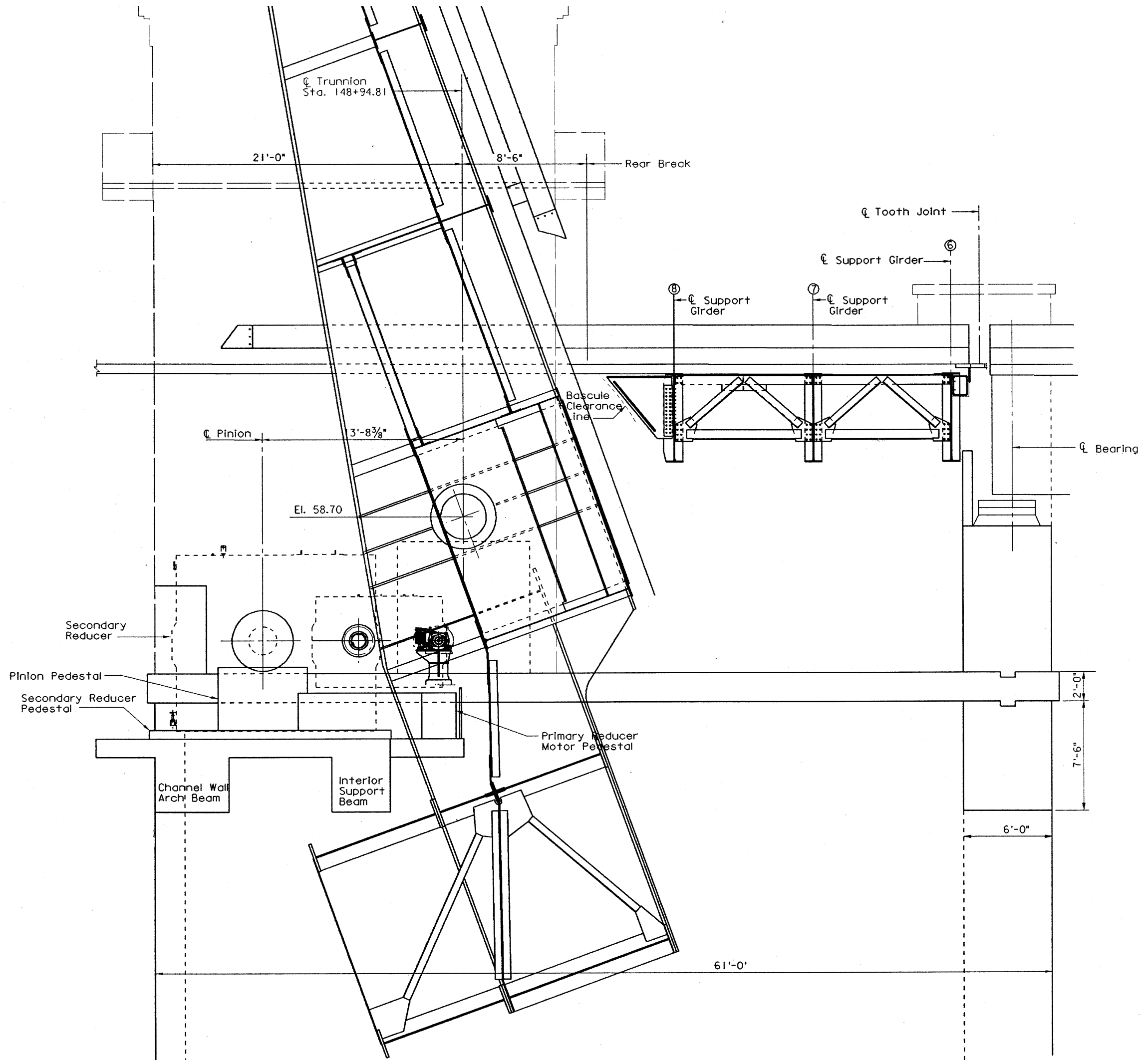

Figure 2 – Trunnion Bascule Schematic

- A traditional trunnion-type bascule (Figure 2) rather than a rolling lift to provide uniformity and economy of maintenance with VDOT’s existing moveable bridge inventory
- Lock bars designed to allow emergency operation using a chain fall

- Oversized reducer gears to allow all moving parts to be immersed in oil at all times
- Automatic high-pressure lubrication system activated from the control panel which lubricates span-mounted and fixed-deck machinery
- Traditional relay-based contactor/resistor control system. Because of the lesser degree of control provided by this system, hydraulic buffers were necessary to cushion the closing impact.
- Two independent drives for each leaf. This nontraditional layout includes two 75HP drive motors for each span, each of which drives a pinion via a dedicated primary and secondary reducer, rather than the more traditional shared primary reducer. As a result, each reducer required twice the capacity of the traditional single-drive system.

Each leaf has two outer bascule girders, each with a rack mounted to the underside that engages a pinion gear on the fixed deck. The mechanical and structural design of each leaf permits it to be opened under normal operation by a single motor driving one pinion and rack. In order to transfer the operating torque from the driven bascule girder to the opposite one, the design includes a torque tube connecting the girders.

This dual-drive system resulted in unusually large machinery components:

- 8’ tall secondary reducers weighing 12 tons
- Pinion gears just under 5 feet in diameter
- 19 foot long, 7 foot tall racks weighing 16 tons with 6” gear teeth at a 14-foot pitch radius

The trunnion shafts are also very large: 32”diameter, 17’ long, weighing 12 tons apiece. (Figure 3)

Figure 3 – Bascule Girder with Trunnion Shaft (interior view)

The engineer's estimate for this machinery was twice that of a conventional design, at a cost of approximately $2m extra, and the bascule spans had to be lengthened by 5 feet to provide sufficient space in the machinery rooms for this large equipment. (Figure 4)

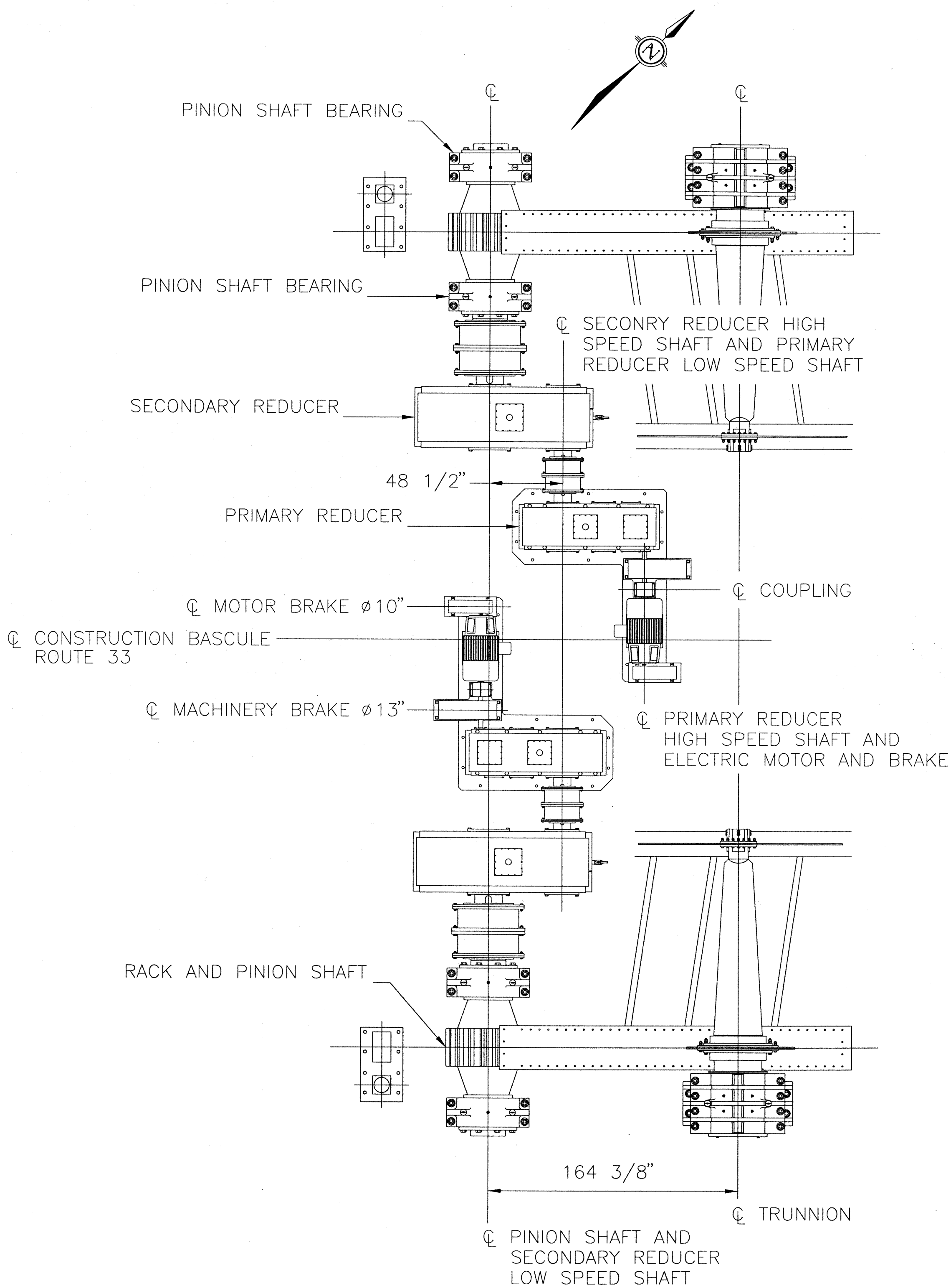

Figure 4 – Machinery Layout: Dual Independent Drive Systems

3. FABRICATION, OFFSITE ASSEMBLY, AND TRANSPORT

Methodology

Machinery manufacture originated at various locations across the US; however, the final machining and point of shipment was Miami, Florida. The bascule steel was fabricated in Palatka, Florida at a facility on the St. Johns River. It was originally planned to ship the machinery components and bascule steel together by barge to Virginia, where the contractor would assemble each bascule into two pieces at an offsite facility. The four preassembled pieces, two counterweights and two leaves, would then be loaded onto two 150’ by 55’ barges and transported approximately 75 miles to the project site, where a 350-ton stiffleg derrick would lift the pieces into position 55’ above the waterway.

However, as fabrication proceeded, the advantages of a revised sequence became clear: assembling the bascule structures on transport barges in Florida, instead of at the yard in Virginia, would provide a significant schedule benefit by allowing assembly to begin during fabrication. This advantage was important, as the bascule work was on the project critical path. The revised sequence also eliminated the requirement for temporary support foundations at the assembly yard in Virginia, as well as for the heavy lifts of the preassembled pieces onto barges in Virginia. Disadvantages of this scheme included the increased towing costs from Florida to Virginia, as two tugboats per barge would be required due to the height of the assembled pieces, and the reduced degree of offsite assembly possible in Florida.

Consideration was given to whether the preassembled pieces, approximately 30’ tall and 77’ wide, would be transported to Virginia via the Atlantic Intracoastal Waterway (AIW) or offshore as an ocean tow. After weighing the costs and risks, the contractor selected the AIW option. However, due to the width restrictions of the inland waterway, only the portion of the bascule spans between and including the bascule girders (approximately 50’ wide) could be preassembled, while the remaining steel outside the bascule girders was shipped loose and was attached upon the barges’ arrival at the jobsite. (Figure 5)

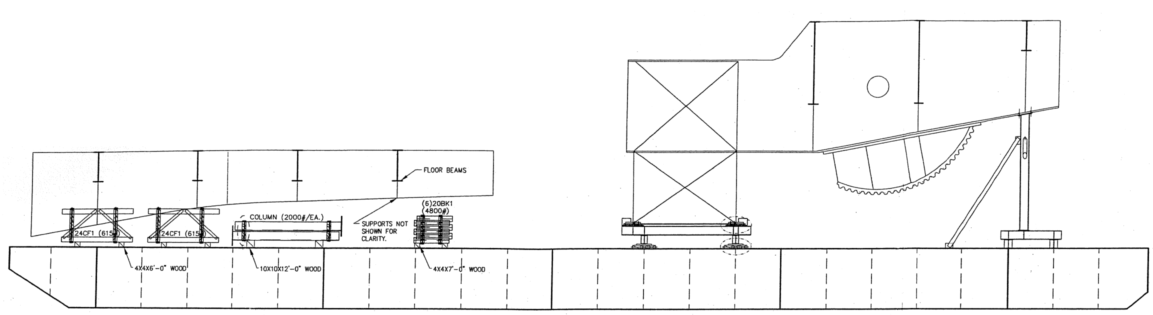

Figure 5 – Barge Transport of Bascule Heel (Counterweight) and Toe Sections

Trunnion Shafts and Hubs

The size and weight of the span-mounted machinery components presented their own fabrication challenges. The trunnion shafts were forged at a facility utilizing a 5,000-ton press—the largest in the country. Careful consideration had to be given to the sequence for fitting the trunnion shafts to the hubs and the hubs to the bascule girders, both of which were specified as ANSI class FN3 interference fits. (Several papers have been written on this topic and varied sequences used in the past.) The size of the pieces, available shop handling equipment, heating and cooling capabilities, and the internal stresses in the hubs caused by the heating and cooling process were all factors to be considered.

The decision was made to fit the hubs to the bascule girders first and then the shafts to the hubs. This sequence reduced the possibility of cracking the hubs due to the high tensile stresses experienced if the hub-and-shaft assembly were cooled externally as a single unit. These stresses would be caused by the faster cooling of the hubs and the slower cooling of the shafts due to their higher thermal mass.

After the hubs were fit to the bascule girders in the horizontal position, these assemblies were heated to 270 degrees F and the shafts cooled to minus 90 degrees in order to fit them to the hubs. (Figure 6) The girder-and-shaft units were then transported outside, rotated into the vertical position, and lifted onto temporary supports on the barges for the initial stages of assembly. Maneuvering the four bascule girder sections with the 12-ton, 17-foot-long trunnion shafts installed perpendicular to the webs required special lifting considerations.

Figure 6 – Fitting the Cooled Trunnion Shaft into the Heated Bascule-Girder Hub

4. ONSITE ASSEMBLY AND ERECTION

Bascule Span Assembly and Lock Bars

Overall bascule geometry and dimensions were controlled by standard survey methods during the initial stage of assembly in Florida. An as-built survey of the leaves was provided to the contractor for use in establishing the trunnion centerlines on site, from which the remaining machinery layout was derived. Once the barges containing the preassembled sections arrived at the jobsite, the remaining assembly was completed. The lock bars and sockets were installed and bolted in their final configuration on the first leaf, while the receiving sockets were temporarily attached to the opposing leaf with undersized bolts until achievement of final alignment. Splice plates were attached on one side of the structural connections and as much of the electrical hardware and lubrication-system piping installed as possible.

Racks and Pinions

The machinery plans prohibited the final alignment, drilling, reaming, and attachment of the racks to the underside of the bascule girders until the spans were set in place and aligned. The racks were originally to be delivered to the steel fabrication yard during assembly in Florida and transported to the jobsite bolted in position on the underside of the bascule girders with temporary bolts in sub-sized holes.

Figure 7 – Temporary Positioning of Rack and Pinion

However, fabrication took considerably longer than anticipated because of factors associated with the size of the racks and pinions. The machine shop had to manufacture custom tooling and use single-index cutting methods for the gear teeth, for instance, and the machining work was limited to the largest equipment in the shop. As a result, the racks and pinions were trucked directly to the jobsite just prior to setting each bascule in place. Temporary supports were designed and fabricated to hang the 16-ton racks 35 feet above the bascule pit floor so that they could be set in place prior to the counterweight sections. In order not to interfere with the setting of the bascules, the racks were set one inch below and about 10 inches forward of their final position. (Figure 7)

The pinion-gear assemblies also had to be set in place, offset forward of their correct position, before the racks and bascule spans were set. The pinions could not be installed in their final configuration, as they would engage the rack and be back-driven when the bascule was opened during initial testing. The pinions could easily be damaged during this back-driving, and their placement would also hinder the rack alignment process. Therefore, coupled anchor bolts were used so the pinions could be slid into position after the racks were aligned and then the upper portion of the anchor bolts installed.

Trunnion Bearings

Each trunnion bearing was set in position over its anchor bolts onto four shim packs on the trunnion pedestals. The bearings were aligned to the trunnion centerline and adjusted based on the assembled leaf as-built survey. The south bearings were set in their final position, while the north bearings were set ½" outside final position to allow clearance between the edge of the bearing and the trunnion shaft thrust collars while setting the counterweight portion of the bascules. These bearings were then jacked into position after the bascules were set. To ensure full bearing on the ends of the shafts, it was necessary to set the bearings with a 0.004" per foot cross slope to accommodate the anticipated deflection in the trunnion shafts once the entire load of the bascule was transferred to the shafts. The maximum allowable out-of-level tolerance was 0.002" per foot, checked using machinist's levels. (Figure 8)

Figure 8 – Trunnion Shaft and Bearing

Trunnion Shaft Alignment

While the bascule steel was still on the barge, the trunnion shafts were aligned by adjusting the position of the square end of the shafts where they pass through the trunnion girders. This was done by driving or withdrawing four tapered wedges between the four faces of each shaft and the trunnion girder web. This alignment accounted for the anticipated bending in the shafts caused by the load transfer to them once the bascule was set. Alignment was checked using a piano wire stretched through the center bore of the shafts. A 72-pound weight was attached to one end of the wire so that the catenary deflection could be calculated and a correction applied.

Erection of the Heel Section

A temporary support structure was erected in the bascule pit to support the counterweight in the closed position after setting. After the live load shoes were set in place, the top halves of the trunnion bearings were removed and the lower halves cleaned. Specially designed and fabricated padeyes were attached to the top of the bascule girders and counterweight box. The heel sections without the racks attached weighed 282 tons and were set in place by the 350-ton stiffleg derrick *Samson* during a one-day closure of the navigation channel. After picking the load off the barge, the crane was shifted into position, using a system of four winches and anchor lines, to set the load in place on the structure. (Figure 9) The orientation of the load in the air was controlled by two air-tugger lines attached to the underside.

Once the counterweight section was close enough to the structure, chain falls and cable comealongs were attached to guide it into its final position on the lower half of the trunnion bearings. The load was carefully set down on the bearings and the temporary supports, checked for alignment, and the rigging unhooked. The weights were reattached to the ends of the trunnion alignment wire and the ends of the shafts checked for being centered on the wire. The top halves of the trunnion bearings were set in place and the live load shoes shimmed to elevation.

Figure 9 – Erection of West Heel (Counterweight) Section

Erection of the Toe Section

The 110-ton toe sections were also set using the stiffleg derrick *Samson.* Each toe section was set on the day following the installation of the counterweight sections. After setting the counterweight sections, the floating crane was pulled back out of position and the toe section was lifted off the barge and suspended from the crane overnight. Care was given to the rigging design to ensure the load hung level to facilitate alignment of the bolted connections between the heel and toe sections. The toe sections were lifted into place first thing in the morning, then the main bascule girder splices were pinned, and by the end of the day's shift, the connections were completely bolted and torqued. (See Figure 10.)

Figure 10 – Erection of East Toe Section

5. CONCLUSION

The Pamunkey River Bridge project featured some unique aspects not only in the design of structural and mechanical components for the bascule spans, but also in the project layout and location which presented special challenges for assembly and erection. The fabrication, assembly, and erection processes were successfully integrated in order to deal with these aspects most efficiently. At the time of writing, the structural portion of the bascules and all machinery is set in place with the leaves shored in the closed position. Counterweight concrete formwork has started and upon completion of this and the roadway decking, final alignment and balancing can begin.

Acknowledgements

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