HEAVY MOVABLE STRUCTURES, INC.
ELEVENTH BIENNIAL SYMPOSIUM

November 6-9, 2006

In Place Machining of Trunnion Journals On Bascule Bridge Rehabilitation

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Wappoo Creek Bridge

The double leaf trunnion bascule bridge was constructed in 1956 and carries Routes SC 171/700 over the Intracostal Waterway. This structure is a vital commuter route from James Island to Charleston through West Ashley in South Carolina (See Figure 1).

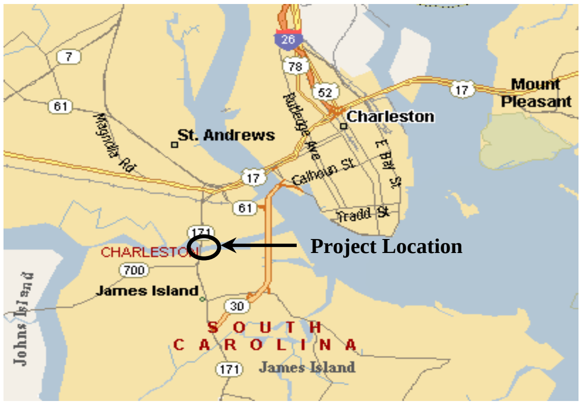

FIGURE 1: Location of Wappoo Creek Bridge over the Intracoastal Waterway.

Each leaf of the movable span is 55 feet wide by 70 foot long that in the open position provides a 100 foot clear horizontal channel on a 6 degree skew to the bridge. The roadway is 50 feet curb to curb and provides three southbound and two northbound 10 foot wide travel lanes. The structure opens approximately 5,000 times per year and is on demand for openings at all times except during morning and evening rush hours, (See Photo 1).

Each of the bascule leaves is supported by eccentric trunnions with pillow block bearings located outside of each of the bascule girders. Each leaf weighs approximately 900,000 pounds.

PHOTO 1: General view of Wappoo Creek Bridge prior to reconstruction

Operation of the bridge did not indicate any adverse conditions to the trunnions except excessive clearances were measured. The trunnion bearings as were not disassembled as part of inspection.

Rehabilitation plans were developed for the structure in 1998 and contract awarded in 1999 to Coastal Marine Construction Incorporated. As part of the complete rehabilitation, the bushings of the trunnions were to be replaced, but one at a time.

The trunnion on this bridge is 18 inches in diameter and the width of the bearing is also 18 inches. The cap of the bearing has a 3/8" babbitt on the inside surface while the bearing base has a 5/8" thick bronze bushing that has 5/8" thick flanges on both sides of the bearing.

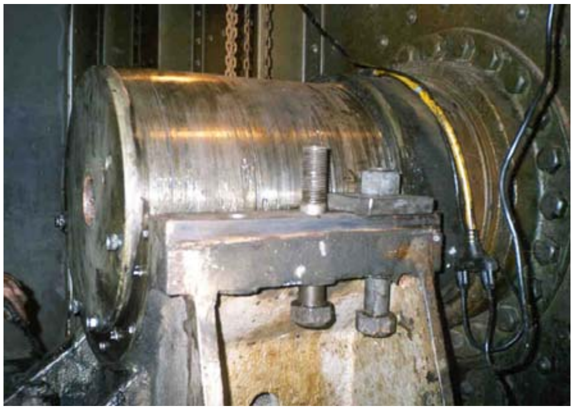

PHOTO 2: Condition of South Trunnion at Wappoo Creek Bridge prior to machining.

The trunnion caps were removed by the contractor to examine the condition of the trunnion journals and obtain field measurements of the trunnion diameter so that the interior bore of the bushing could be machined to the proper tolerance. Both north trunnions were in very good condition with only slight scoring present. When the south, or farside, trunnion caps were removed, the journals were in very poor condition (See Photo 2). These journals had scores up to 0.060” deep and pits up to 0.010” deep throughout the full length of the journals and the shoulders had been gouged. Condition of the bushing could not be determined but based on observations of the trunnion journal the bushing was not going to be in good condition.

It was determined that the trunnion journals for the south leaf could not be left in this condition. Replacement of the trunnion was determined to be too timely and cost prohibitive. The only viable option was to remachine the existing trunnion on the bascule span. Although the trunnions on the north leaf were in good condition, it was decided that all trunnions should be remachined to the same diameter. The condition of the babbitt in the caps was good and it was determined no work would be performed on the caps except for cleaning of the babbitt and grooves.

The first task was to estimate the amount of material that would be required to be removed to eliminate the scoring. Based upon the field conditions the largest visible score was 0.060” deep. Therefore it was determined that 1/16” of material was to be removed all around or reduce the trunnion diameter by 1/8” maximum allowed by the stock in the bushing. This amount was to be taken from the full width of the trunnion and the fillet radius was to be feathered to accommodate the new diameter of the trunnion. The bushing bores had not yet been machined at this time and extra stock had been placed to allow final machining of the bushing bore after field measurements were obtained. This allowed the inside diameter of the bushing to accommodate the revised diameter without having to fabricate new bushings.

Prior to the commencement of any work in the field, new analysis of the trunnions was performed. This was done to assure that the smaller trunnion diameter and the bronze bushing would not be overstressed from the loading condition. An eccentric shaft acts as a simple beam with a cantilevered overhang. For this type of beam, the maximum moment occurs at the bascule girder (nearest reaction) and therefore the reduction in area is not a factor for the trunnion. It does affect the bearing stress and analysis showed that bearings were not overstressed based on AASHTO guidelines. Shear stress of the trunnion was also examined at the reduced diameter section.

The jacking was to be performed by Seacoast Metal Products, subcontractor to Coastal Marine Construction and the Machining by Steward Machine Company.

The jacking was to be performed by installing two jacking columns under each bascule girder. Four 280 ton jacks were utilized to lift the span, one place on each of the jacking columns. Two of the jacks were set in front of the centerline of trunnion and two were set behind the trunnion. This was done to provide stability about the span’s center of gravity when lifting. All four jacks were powered from the same power unit, but each jack was individually controlled to allow for controlled raising of the span. The front column was short and mounted on the pier at machinery level. The rear column was about three times longer and mounted on a shelf of the pier near water level. A beam had to be installed under the column to ensure the load of the span was transferred to a portion of the pier thick enough to resist the jacking loads. Both columns were then longitudinally braced to one another (See Figure 2). To ensure the load would not locally overstress the bascule girder, an additional angle was installed to act as a web stiffener for the front jack. The rear jack was already acting on a heavily reinforced section since the front counterweight floorbeam connected to the bascule girder at that location.

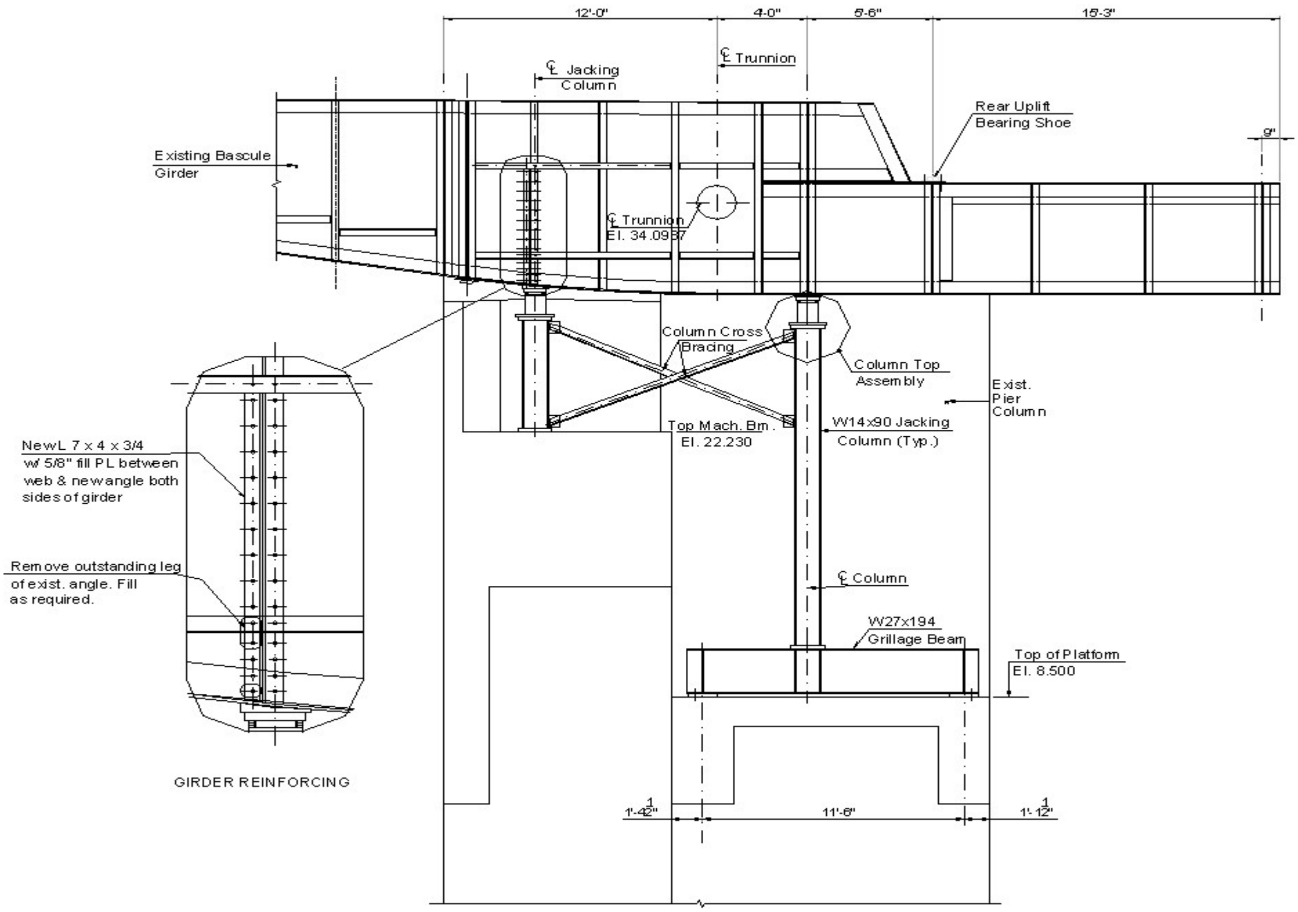

FIGURE 2: Elevation view of jacking system under one girder of Wappoo Creek Bridge.

The work was to be performed in two phases, first the south leaf trunnions were to be repaired and then the same jacking equipment would be moved over to the north leaf and these trunnions would to be repaired. The jacking was to raise the leaf a sufficient amount to allow the trunnion bearing base to be lifted over the anchor bolts and be removed, a height of approximately 6 inches. It was necessary to remove the base to provide sufficient clearance for the equipment necessary to machine the trunnion journal in place and to fit the new bushing into the existing bearing base. Jacking was to occur with an overnight roadway closure. The leaf would be raised to remove both bearings and then the leaf lowered and set back on live load shoes to reopen to vehicular traffic. Machining one leaf at a time was performed to allow single leaf operation for mariners. Since the machining was a lengthy process this would be done at night with no live load on the bridge for a few consecutive nights.

The set up of the jacking equipment was done during the day as well as the removal of the rear live load shoes and disconnection of the operating machinery. The jacking and bearing removal was performed that night with the roadway closed. Jacking commenced at about 12:00 am. A person was stationed at the front and rear live load shoes of each girder enabling them to take measurements at all four locations to assure equal lifting in both the transverse and longitudinal directions. They also turned the locking collars as the lift progressed. The raising of the span took approximately 3 hours to perform. The span was lowered and set back on the front live load shoes and the rear shoes were reinstalled and the structure was opened to vehicular traffic by 7:00 am.

The machining of the trunnion was performed in 5 nights of work in August of 1999 that would be done in five steps. Step 1 was the rough cut. On this pass 0.050" was removed from the trunnion diameter (See Photo 3). Step 2 was to remove 0.030" from the trunnion journal diameter, step 3 removed 0.010", step 4 was to recut the trunnion shoulder and step 5 was to grind and polish the machined surface and grind out the lubrication grooves (See Photo 4). Each pass took approximately 4 hours to complete.

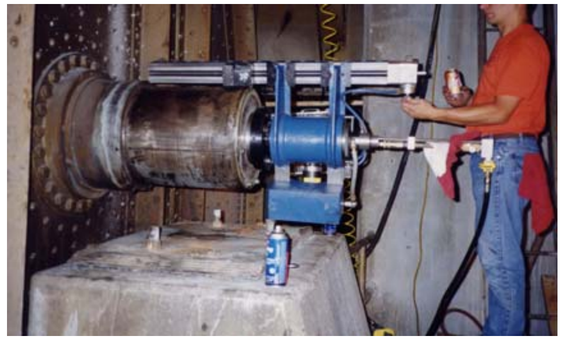

PHOTO 3: Machining equipment set on trunnion for Wappoo Creek Bridge

After both trunnions were finished and the final diameter of the shaft established the bushing was machined for the proper tolerance and set into the bearing base. The base was brought back to the site and over night the bridge was jacked up again to install the bearings and then lowered. The existing shims under the trunnion bearings were previously removed and the bearing was realigned at the proper elevation and grouted into place.

PHOTO4: Trunnion journal for Wappoo Creek Bridge after completion of machining

Alignment of the trunnions was checked with the use of a piano wire across the width of the span. Adjustments were performed using the eccentric nuts on the interior end of the trunnion and the leaf was then operated to ensure proper function.

The north side trunnions were in better condition and the process was repeated in May of 2000 and the machining completed in 4 nights.

Wrightsville Beach Bridge

Located to the east of Wilmington, NC this double leaf bascule bridge over the Intracoastal Waterway provides the only access to the beach community of Wrightsville Beach (See Figure 3). . The movable portion of the structure is very comparable to the Wappoo Creek Bridge in SC in that it is a double leaf trunnion bascule bridge that is operated by a Hopkins Drive machinery configuration and also utilizes

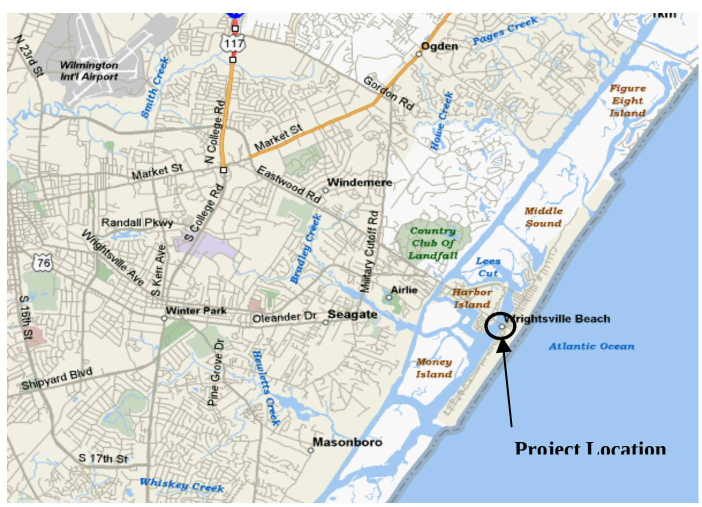

FIGURE 3: Location of Wrightsville Beach Bridge over the Intracoastal Waterway.

eccentric trunnions. The bridge was also built around 1956. The structure's roadway travels in the east west direction and provides a 90 foot clear channel on a 5 degree skew through a bascule span that is 133 foot centerline to centerline of trunnions. Each of the movable spans is 66 feet wide and 66 feet long. The 56 feet curb to curb roadway provides two travel lanes in each direction plus shoulders (See photo 5).

PHOTO 5: General view of Wrightsville Beach Bridge over the Intracoastal Waterway.

The trunnions are 19 inches in diameter and 18 inches wide with 3/8 inch thick babbitt in the cap and 3/4 inch thick bronze bushing in the base. Each leaf weighs approximately 1,300,000 lbs.

The trunnions had shown signs of distress and continued inspection showed the southwest trunnion was damaged with a cracked bushing that also had a portion of the flange broken off (See Photo 6). In September 2000, NCDOT contacted TIC- The Industrial Company to provide a cost estimate for the repair to the west leaf trunnions and replacement of the bushings. The estimate was $226,415, but NDCOT decided against proceeding with a negotiated contract and advertised for bids in a special December 21st letting. TIC was low bidder ($313,395) and was awarded the contract on December 27th. Due to the similarity of the Wrightsville Beach Bridge to the Wappoo Creek Bridge and HNTB's experience with the trunnion repair, TIC contacted HNTB to assist in the design and jacking of the structure.

PHOTO 6: West Trunnion of Wrightsville Beach Bridge showing cracked bushing and section of flange missing.

As with Wappoo, four jacking columns were to be utilized, but due to the increase in the span weight, eight jacks of 150 tons each were utilized. These were set up in pairs on each column. Although it would make the jacking a little more difficult due to coordinating more jacks, this was done to facilitate the load distribution to the girder as well as make the size of the jacks more manageable to handle.

The substructure was quite different on Wrightsville and the development of the jacking columns load transfer required some more conservative design than on Wappoo. This was due to the portion of the pier directly below the bascule girder being only a small ledge (approximately 26 inches wide). The original contract documents called for all concrete to be 3,000 psi, but there was a note on the footing plans calling for the minimum compressive strength of the footing concrete to be 1,000 psi. Since the top of footing was at elevation +1.0 the footing is constantly being submersed in seawater and the overall integrity of the concrete was in question. Both these conditions raised considerable concern during the design of the jacking system. The design concern was the failure of the concrete in shear due to exceeding the allow stress on concrete according to AASHTO. This concern of the strength value of the footing concrete resulted in TIC obtaining a core sample to determine the structural integrity of the concrete. Core samples showed the concrete to have a corrected compressive strength of 3,300 psi, better than called for on the plans and the design was completed (See Figures 4 and 5).

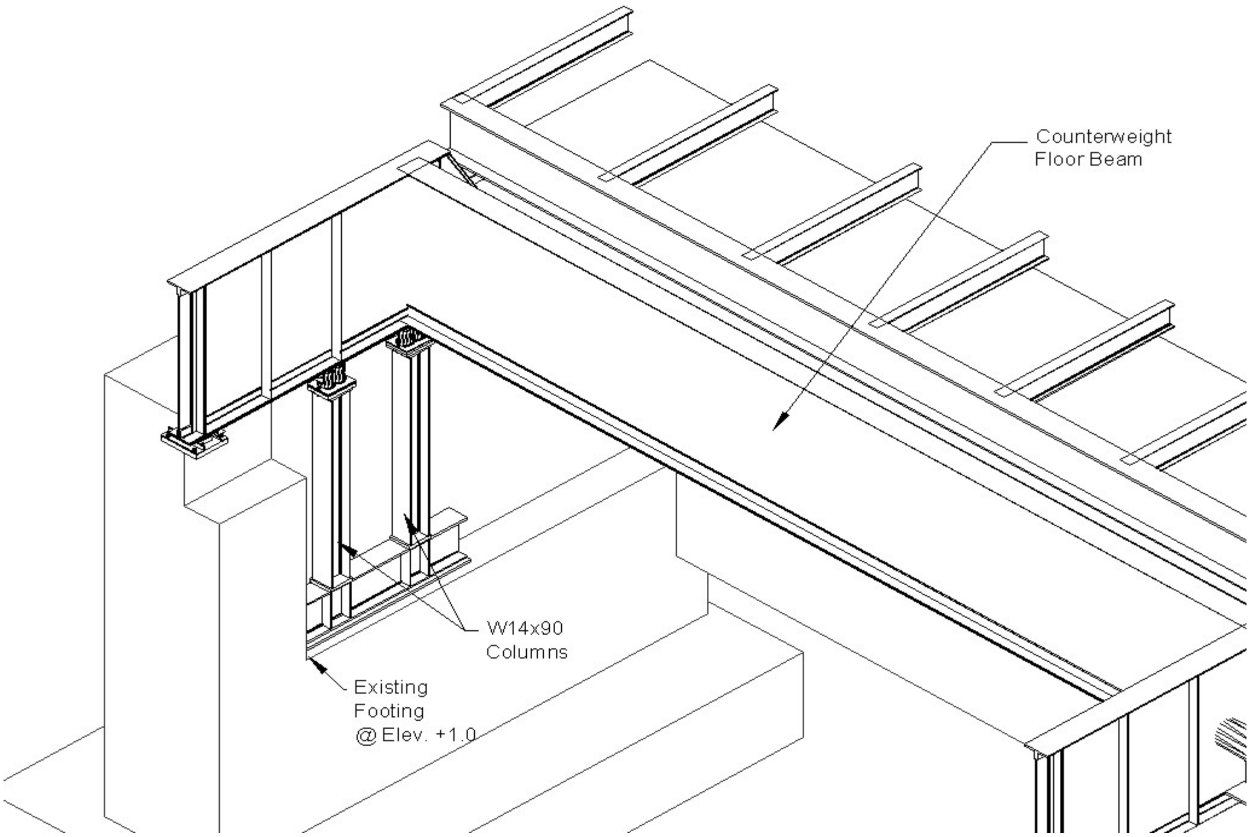

FIGURE 4: Isometric view of jacking system for Wrightsville Beach Bridge

The plan for the repair was to have the west leaf closed to marine traffic for only 23 days and to have maximum of 8 nighttime closures to vehicular traffic for jacking of the spans and machining the trunnions. The 23 day time frame included installing the jacking frame, placing a temporary span lock drive system, jacking the bridge to remove the bearings, machining the trunnions, replacing the bronze and babbitt bushings, re-jacking the bridge to place the rehabilitated bearings and removal of the jacking frame to allow for full bridge operation. Machining of the trunnions was performed with no vehicular traffic on the span. Since the bridge was the only route on/off the island NCDOT set up a bus/taxi service on either side of the bridge to assist late night travelers in getting to their destinations. Emergency crews were place on the island side of the bridge with the understanding that if a severe emergency arose fire and ambulance service vehicles would be permitted to cross the bridge. Local hospitals set up their own shuttles for staff that lived on the island to provide transportation to and from the hospitals.

The structure configuration proved to make things difficult for the repair. First was that there was limited room around the existing trunnions for setup of the required machining tools. The south side had a plywood wall separating the pit area and the electrical room. The north side had the exterior wall of the bascule pier. The south plywood partition wall, span lock and span limit switch were removed to provide room at the SW trunnion. A section of the north wall was removed providing not only room to set the machining bar but also provided an access hatch to remove the bearing (See Photo 7). Second was the span lock system consisted of a series of cranks and linkages that passed through the trunnion on the south side of the span. To perform the machining, the portion of the span lock going through the trunnion

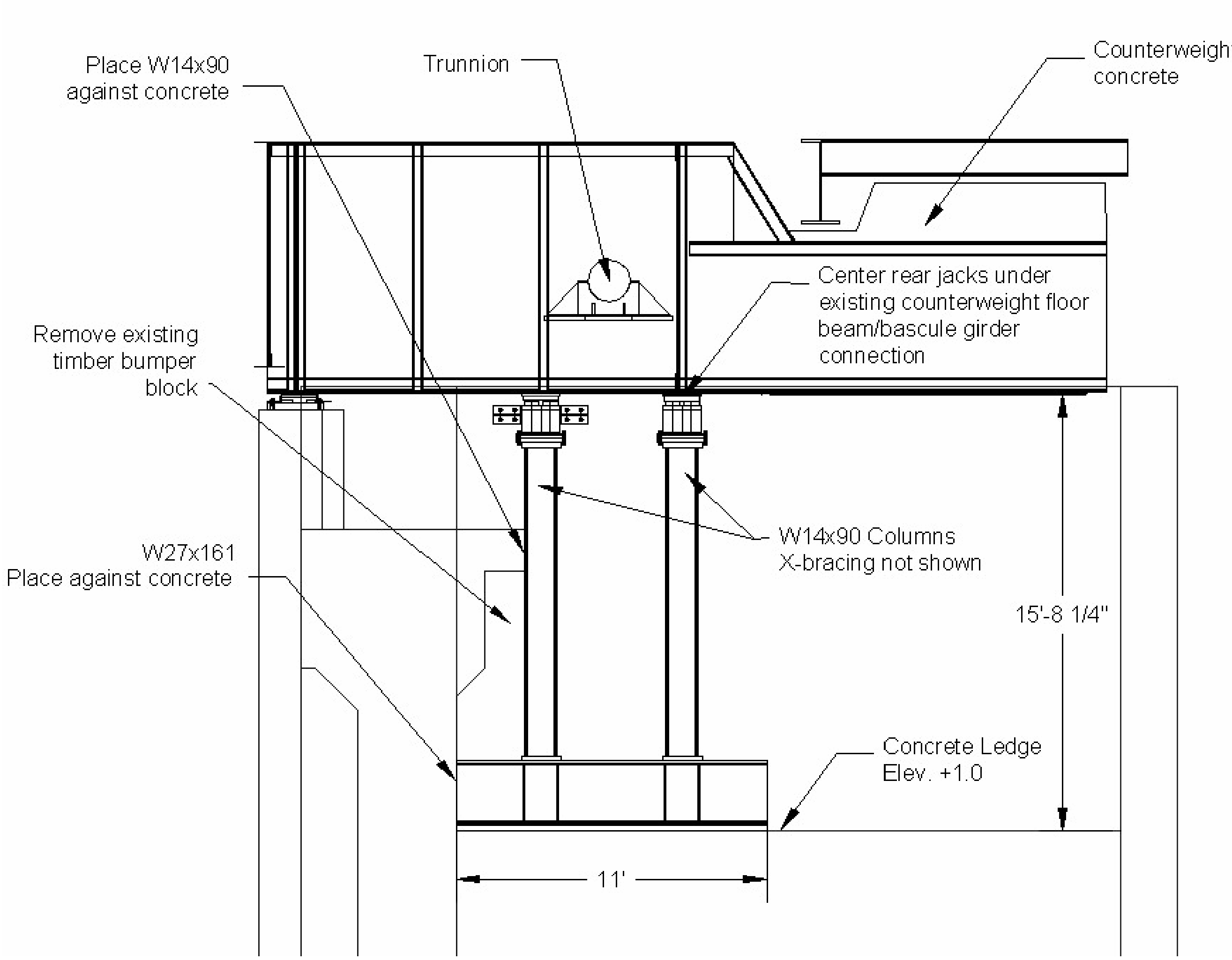

FIGURE 5: Elevation view of jacking system. Note transverse beam directly above counterweight

had to be removed, but the span locks had to remain operational. This was done by installing a temporary hydraulic cylinder to replace the crank that passed through the trunnion. Also the span control equipment had to be temporarily removed since this was connected to the outside face of the trunnion.

The jacking procedure was also more complex due to the structural conditions. The rear live load shoe is mounted to a transverse beam that is directly above the counterweight. Even with removing the rear shoe there was inadequate clearance to properly clear the anchor bolts when the span was raised. To obtain even greater height of the lift, the span was slightly rotated by raising the front jacks higher than the rear and then raising both simultaneously. This allowed the bascule span to go higher while keeping clear of the transverse beam.

PHOTO 7: Machining system in place on trunnion. Note hole in pier wall to provide clearance.

The repairs to west leaf trunnions occurred in February of 2001. During this time the west leaf was closed to marine traffic and single leaf operation was performed to allow the passage of marine traffic. The jacking was done in one overnight closure of the roadway and the machining of the trunnion was done overnight for 6 nights.

After the completion of the west leaf, the trunnions on the east leaf were monitored and after three years, a crack appeared on the southeast trunnion. This resulted in the requirements to machine both trunnions of the east leaf in February of 2004 with a contract value of $378,000. These repairs would mimic the repair that was performed in 2001.

Again NCDOT let the contract out to bid and TIC was awarded the repair contract.

Both repair contracts proceeded well and the machining of the trunnions was a success (see Photo 8).

PHOTO 8: Completed Trunnion and Bearing for Wrightsville Beach prior to assembly.