HEAVY MOVABLE STRUCTURES, INC.
FOURTEENTH BIENNIAL SYMPOSIUM

October 22 – 25, 2012

Machinery Rehabilitation of the Court Street Bridge Over the Hackensack River, Hackensack, New Jersey

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Introduction

The Court Street Bridge is located over the Hackensack River in Hackensack, New Jersey. The Court Street Bridge is a Symmetrical Center Bearing type Swing Bridge spanning east and west, built in 1908. The project included the complete redesign and replacement of the mechanical and electrical systems as well as rehabilitation of the movable and fixed superstructures of the bridge. As part of this work, the center and rest piers and approaches were demolished. The movable span was dismantled so that the trusses could be salvaged and rehabilitated; new steel was provided for the roadway support.

TranSystems (formerly Lichtenstein Consulting Engineers out of Paramus, New Jersey) was the prime consultant for the work. TranSystems provided construction engineering support to the owner throughout construction. Stafford Bandlow Engineering, Inc. served as sub consultant to TranSystems and provided advisement on the construction of the movable bridge mechanical and electrical systems.

Mechanical Design

Overview

The machinery for the bridge is categorized into four systems: Span Support, Span Drive, Live Load Support and Centering Device. Save for a few components found to be obsolete, the rehabilitation design for the mechanical systems utilized the basic design concepts used in the existing bridge.

The span support system functions to both support the weight of the bridge and provide the required stability needed for bridge operation. It is comprised of two sub systems: Center Bearing and Balance Wheels and Track. The two serve two distinct functions to meet the same end. That is the Center Bearing is designed to support the whole weight of the bridge, while the Balance Wheels and Track serve to stabilize the span throughout operation.

The Span Drive system functions as the sole moving mechanism of the span.

The Live Load Support System serves to absorb the live loads of traffic and any other external forces encountered by the bridge while it is in the closed position.

The bridge is centered by utilizing a rigid stop which physically prevents the bridge from over travel when closing.

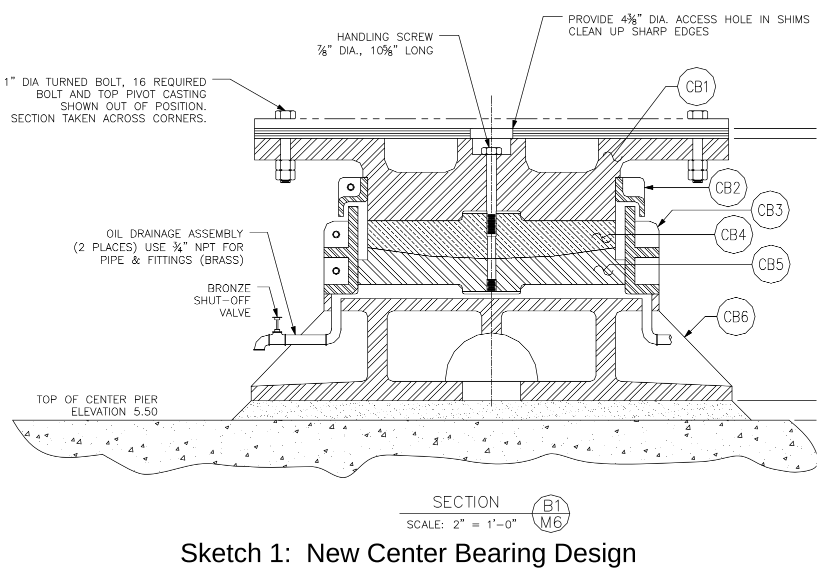
Span Support

Center Bearing

The function of the center bearing is to support the weight of the movable span. The existing center bearing was a "Pumpkin Seed" configuration consisting of three disks: an upper and lower concave steel disk and a middle double sided convex bronze disk. Due to an inherent instability issue identified thru historical usage, the three piece design has been abandoned in modern design.

Photo 1: Existing Center Bearing

The new Center Bearing utilizes a spherical plain bearing comprised of two mating spherical disks: an upper bronze disk (CB-4) and a lower steel disk (CB-5). By virtue of the spherical geometry of the disks, the bearing is allowed three degrees of rotational freedom. The center bearing is immersed in an oil bath contained by the oil box (CB-3). Lubrication is spread to the mating surfaces on the disks via radial grease grooves in the top disk. The oil box is split into two pieces which facilitates easy removal of the oil box for access to the exterior surfaces of the disks for future inspection or rehabilitation.



Sketch 1: New Center Bearing Design

In recognition of the infrequent usage that the bridge would see, a concern existed that the clearance provided in the original design resulted in limited contact which could result in flattening of the contact regions over time. The design featured more evenly matched radii in accordance with standard design philosophy for running machinery clearances which provided improved load distribution to mitigate this possibility. Multiple radial grease grooves which extend from the edges to the center of the disks were provided to ensure oil distribution to the contact surface of the bearing. This design methodology had been previously employed with demonstrated success at the East Haddam Swing Span.

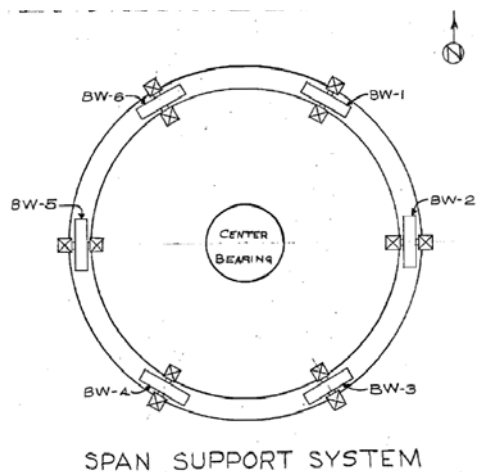
Photo 2: New Center Bearing
(Oil box and dust skirt removed)

Photo 3: New Center Bearing
Upper Bronze Disk

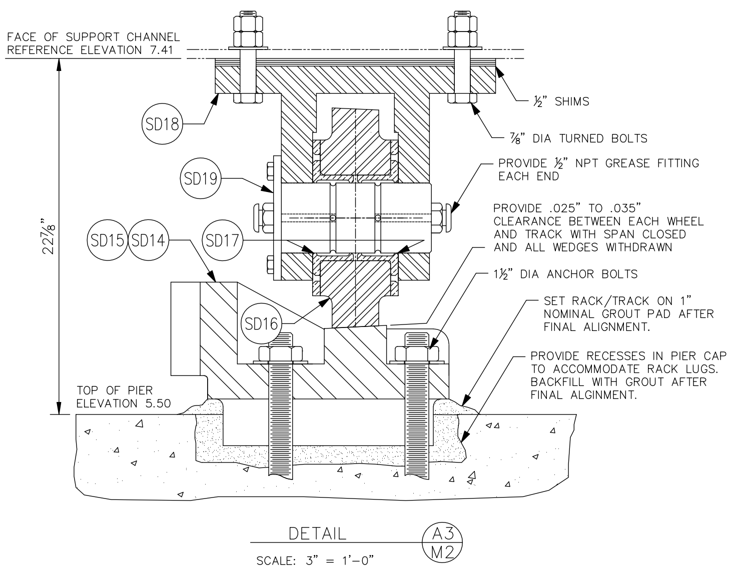
Photo 4: New Center Bearing
Lower Steel Disk

Balance Wheels

While the Center Bearing supports the weight of the bridge, the balance wheels serve to stabilize the span from overturning during operation due to imbalance and/or external loads such as wind, ice, or rain. The original design used six balance wheels to provide this function. The balance wheels are installed with a nominal gap of approximately 1/32" between the wheel and track since function of the balance wheels is to limit movement not to carry load. The balance wheel system was redesigned with eight equally spaced balance wheels in accordance with AASHTO.



Sketch 2: Original Balance Wheel Arrangement. Sketch taken from 1980 inspection report.

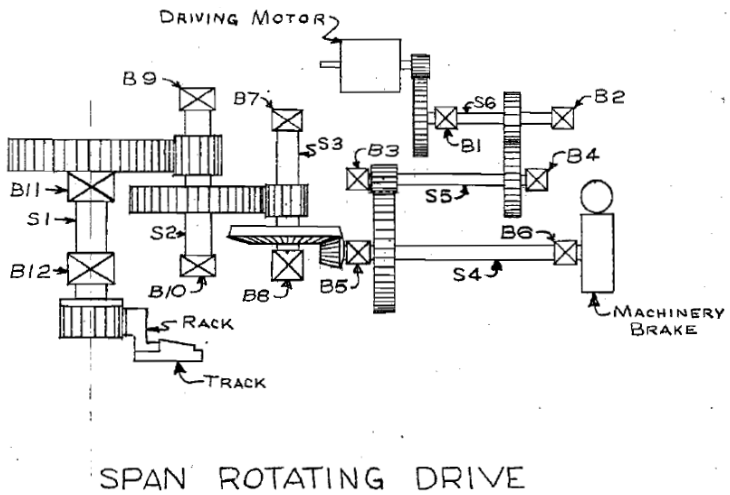


Sketch 3: New Balance Wheel Design

Photo 5: Redesigned Balance Wheel

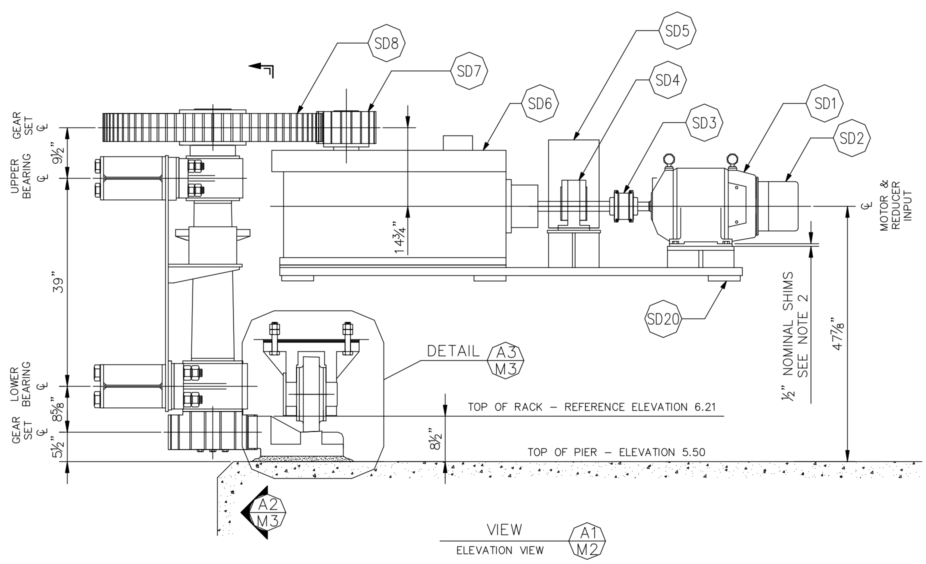
Span Drive

The original span drive machinery consisted of a single 30 hp motor, machinery brake and a series of five open gear set reductions providing the torque to the input gearset at the vertical rack pinion shaft. The span was driven by a rack and pinion gearset where the rack was a full circular ring gear centered about and anchored to the center pier.



Sketch 4: Original Span Drive Machinery Arrangement. Sketch taken from 1980 inspection report.

As part of the rehabilitation, the objective of the machinery redesign was to provide a robust machinery system that would provide for long term reliability under minimal maintenance. In addition, the machinery would see infrequent operation and have exposure to weather ranging from extreme cold to high heat. Various options were investigated. Hydraulic systems were dismissed over concerns that they systems would not prove reliable given the intended usage and minimal maintenance. Ultimately, a standard electro-mechanical system was chosen for proven durability under the design conditions.
Due to the intended infrequent operation and to minimize costs, the bridge was limited to one direction of operation with the drive machinery confined to one quadrant. This minimized both the quantity of machinery components as well as the number of rack segments.



Sketch 5: Redesigned Span Drive Machinery

To minimize maintenance requirements, the new machinery was redesigned to eliminate open gearing to the extent possible. The final rack pinion and ring gear remain by necessity; however the ring gear segments have been minimized as indicated above. Due to the limited space between the top of pier and bottom of roadway, it was not practical to provide all remaining reduction in one reducer while also providing adequate support to the rack pinion shaft. Therefore, the machinery arrangement utilizes one primary gear reducer which drives the rack pinion shaft through an open gearset. The primary design features of this arrangement include:

- The elimination of open gearsets to the extent practical to improve the efficiency and reliability of the drive while minimizing maintenance requirements.
- Providing the majority of the drive components on a common frame allows for shop installation and alignment and limits field work to the alignment of two primary sub systems: the primary machinery frame and the rack pinion shaft assembly.
- The sole open gearset is located between stringers immediately under the roadway which provide protection against exposure and accidental contact.
- The rack pinion shaft is simply supported by a mounting plate/support beam subsystem beams that was custom designed to limit deflection of the imposed machinery loads while allowing shop setup and alignment of the bearings on the support frame.
- The rack segments were designed with lugs that would be embedded in the center pier to provide a more secure mounting than through anchor bolts alone.

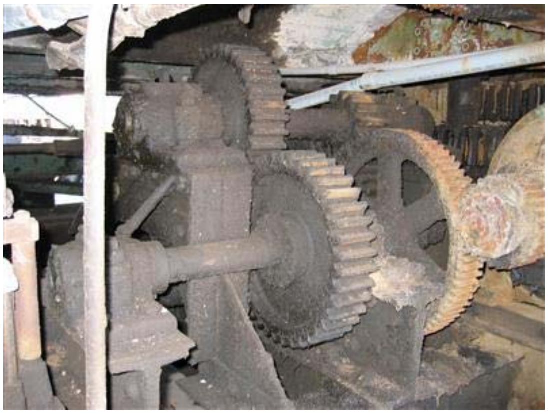


Photo 6: Original span drive gearing

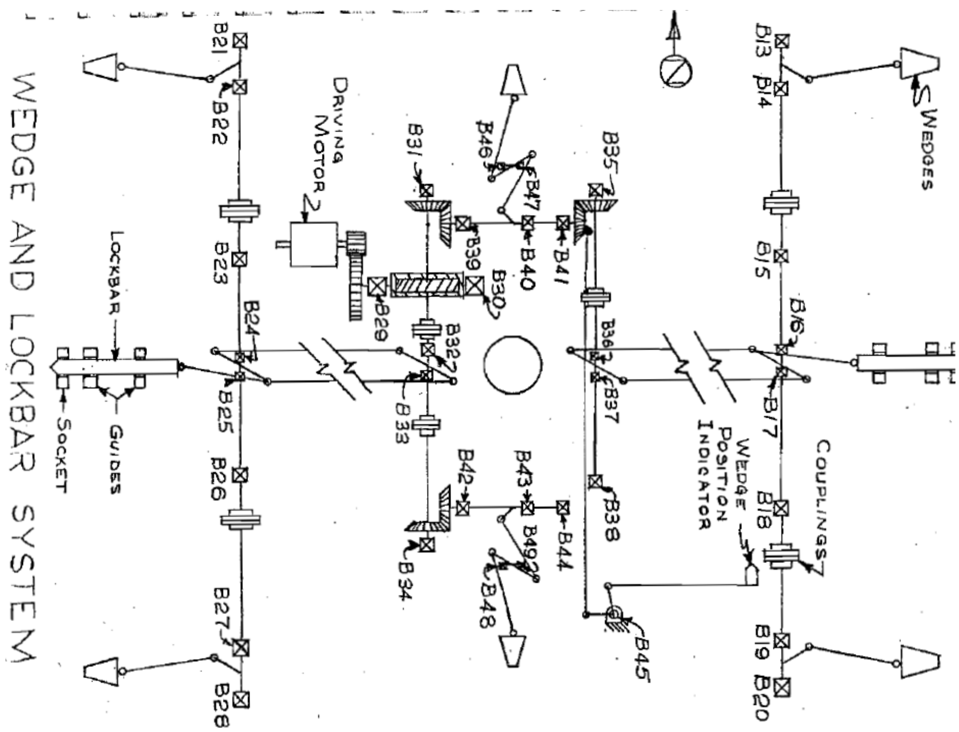
Photo 7: Redesigned Span Drive Machinery

Photo 8: Original Rack and Balance Wheel and Track

Photo 9: Redesigned Rack

Live Load Support

Wedges were used to provide uplift to compensate for deflections at the ends of the span, stabilize the center of the span, and to support live loads of traffic. The wedge system consisted of four end wedges and two center wedges. The end wedges were located at each corner of the span and the center wedges were located at transversely opposite ends along the bridge centerline. All wedges were previously driven by common machinery driven by a common motor. The mechanical power was transferred through an elaborate series of open gear reductions and linkages.



Sketch 6: Schematic of end and center wedge and lock bar machinery. Sketch taken from 1980 inspection report.

The following changes were made to the live load support system to improve efficiency and reduce maintenance requirements:

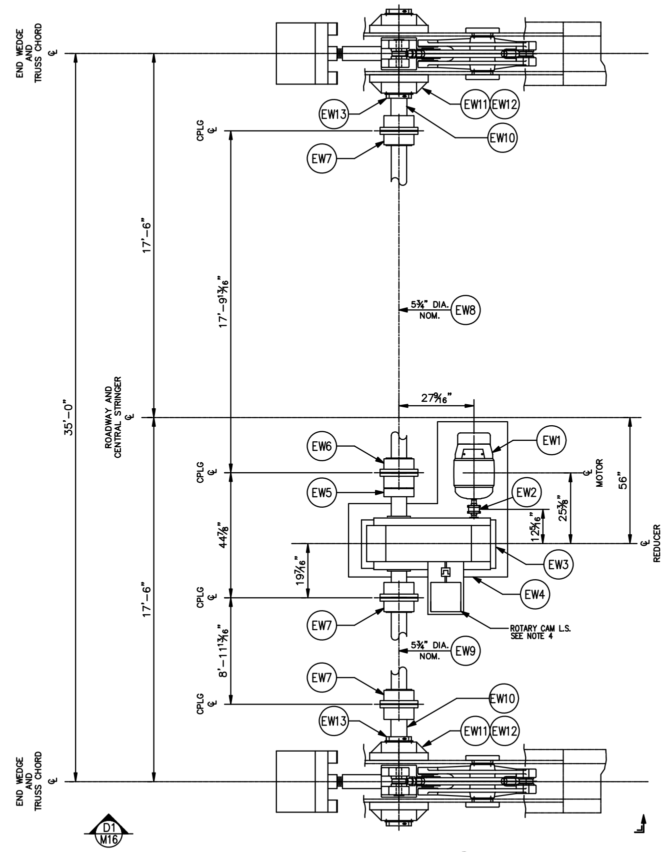
- Independent drive systems were provided for the east and west end wedges and center wedges.
- Open gearing was eliminated and replaced by fully enclosed gear boxes.
- The machinery was mounted on common frames where possible to facilitate alignment

End Wedges

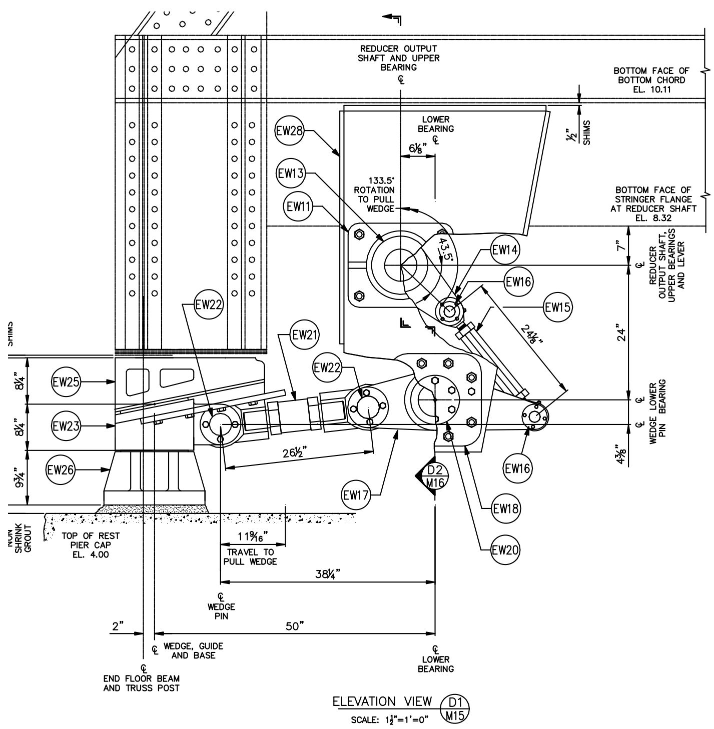
At each pair of end wedges, a 7.5 hp electric motor drives a fully enclosed reducer which distributes the power to two output shafts. The output torque of the reducer is transmitted to each of the two crank frames via floating shafts. The crank frames house a series of internal cranks, shafts, and connecting rods which convert the input torque to the force required to drive the wedges in place.

The primary design features of this arrangement include:

- Machinery sized for a 65/35 torque split at the reducer output in consideration of the reality of unequal loading at the wedges.
- At the same time, a ringfeder shrink disc was provided on the cross shaft to provide infinite adjustability to optimize indexing of the wedges and minimize the likelihood of unequal loading.
- A common frame was provided for the corner linkage so that the crank linkage could be shop assembled and aligned.   Spherical connecting roads were provided at the connection to the wedges to further minimize alignment requirements.



Sketch 7: Schematic of end wedge machinery



Sketch 8: Elevation view of end wedge crank frame.

Photo 10: Original End Wedge Machinery.

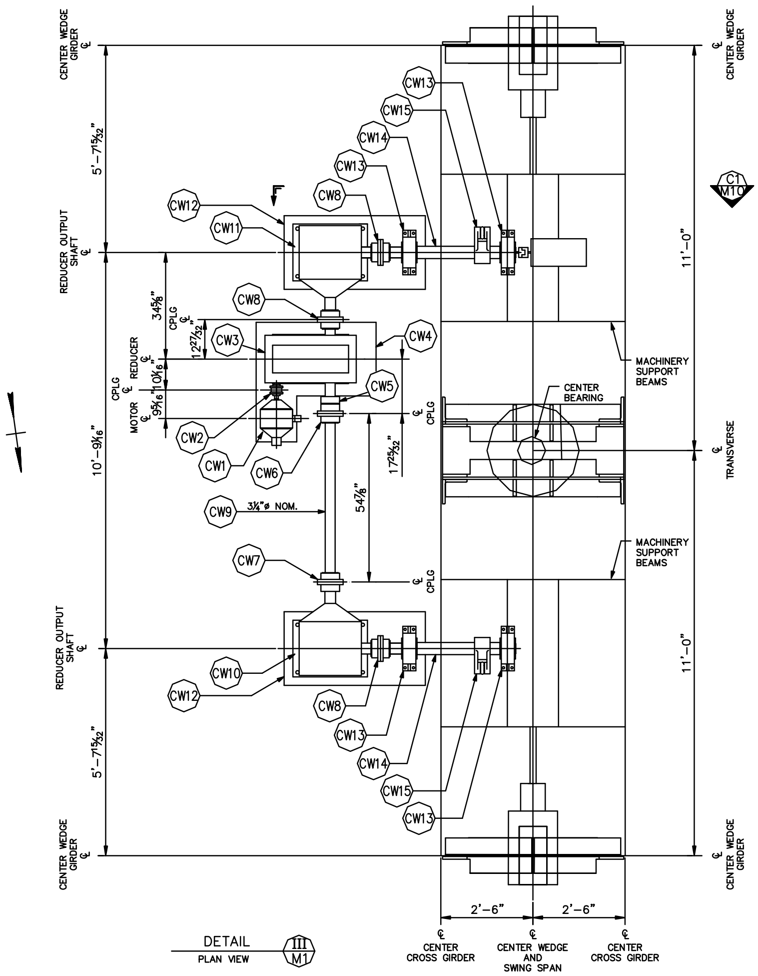
Photo 11: New end wedge machinery (outboard side)

Center Wedges

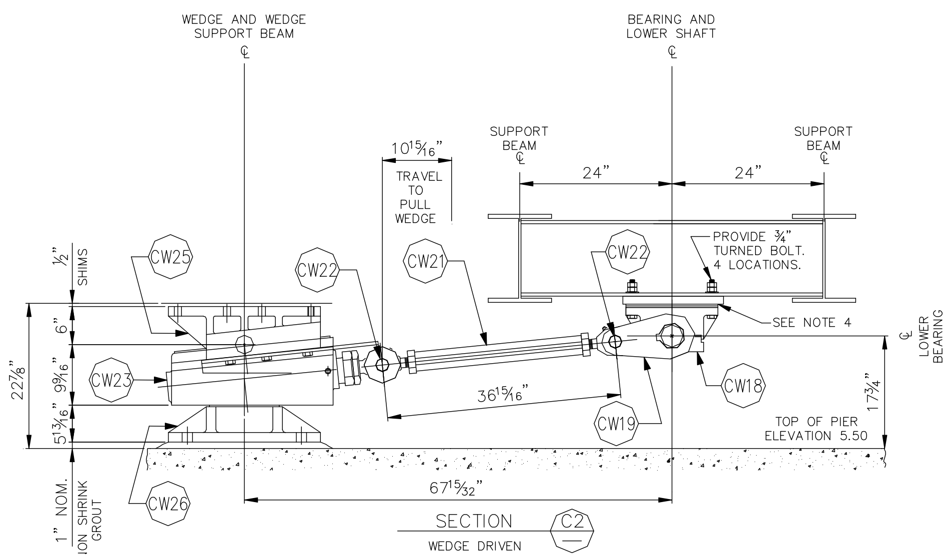
At the center wedges, a 1.5 hp electric motor drives a fully enclosed reducer which distributes the power to two output shafts. The output torque of the reducer is transmitted to two right angle gear boxes which serve to change the direction of the torque. The output torque of each right angle reducer is then transferred to a series of cranks and connecting rods where the torque is then converted to the force required to drive the wedges in place.

The primary design features of this arrangement include:

- The bridge framing in the vicinity of the center wedge machinery minimized the extent to which the machinery would be pre-assembled. However, where possible, the primary machinery components were mounted on shop assembled frames.
- The center wedges are spring loaded to prevent overload and excessive loading of the machinery.



Sketch 9: Schematic of center wedge machinery



Sketch 10: Elevation view of center wedge machinery.

Photo 12: Original Center Wedge and Center Wedge Machinery.

Photo 13: Top view of new center wedge.

Conclusion

The design was completed in 2004. Due to funding, the project was not awarded until 2009. The rehabilitated bridge was opened to traffic on September 7, 2012.