HEAVY MOVABLE STRUCTURES, INC.
FOURTEENTH BIENNIAL SYMPOSIUM

October 22 – 25, 2012

Machinery Replacement for the Port Severn Swing Bridge (Bridge 60) over the Port-Severn Waterway in Ontario, Canada

Krishna H. Mehta, P.E.
Stafford Bandlow Engineering, Inc.

CARIBE ROYALE HOTEL
ORLANDO, FLORIDA

Introduction

The Port Severn Swing Bridge (Bridge 60) is owned and operated by Public Works Government Services Canada and is located over the Port-Severn waterway in Ontario, Canada. The bridge was replaced in 2011 as part of a recapitalization project by Public Works Government Services Canada. The swing bridge is 28.5 meters (93.5 ft) long and 5.2 meters (17 ft) wide and weighs approximately 34,900 kg (77 kips). The swing bridge is operated using hydraulic cylinders and supported by a center bearing. In the open position (channel open) all the bridge weight is supported by the center bearing and any external loads, such as wind, ice and imbalance is taken by the balance wheels and track. In the closed position (channel closed) the bridge is supported at the middle by the center bearing and the east end is supported by end casters and the west end is supported by end wedges. This enables the swing bridge to be fully supported when open and act like a fixed bridge in the closed position.

This project started with an initial inspection to determine the scope of the rehabilitation project. In this inspection it was determined that all span support machinery and locking pin machinery components were in generally poor condition and replacement was warranted. It was also determined that the span drive machinery components were in fair condition and nearing the end of their service life. Therefore the scope of work included the replacement of all span support and span drive machinery. Stafford Bandlow Engineering, Inc. (SBE) provided the design and construction services for the mechanical, electrical and hydraulic machinery for this project as a subconsultant to Delcan.

The design of all machinery was improved in terms of function, ease of installation, ease of maintenance and longevity. All components were upgraded to meet the CAN/CSA-S6 Canadian Highway Bridge Design Code (CHBDC) requirements. Shop drawings were reviewed to ensure adherence to the contract plans and specifications. Construction services were provided to ensure that all machinery installation and alignment was in accordance with the shop drawings and contract plans and specifications.

The rehabilitation design was completed in December 2010 and the construction was completed at the end of 2011.

Inspection Findings

A condition assessment inspection at Bridge 60 over the Trent-Severn Waterway in Port Severn Ontario was performed on April 5-6, 2010. The findings of this inspection are as follows:

Center Pivot

- Maintenance personnel reported that when the lubricant in the pintle is purged the lubricant contains abrasive contaminants and debris.
- During operation, rust colored water escaped from the interface of the bearing surface, corroborating the notion that the pintle design lends itself to contamination.
- The upper casting which is mounted to the pivot girder was in poor condition and exhibits heavy corrosion, particularly of the mounting fasteners which have nearly 100% section loss.

Span Drive Machinery

The HPU and control system provides for semi-automatic control defined as follows: The fluid flow automatically increases from zero to normal volume and back to zero again for span acceleration and deceleration by the operation of a single hand lever. The HPU only provides for single speed operation and there is no ability to operate the span at a constant, reduced speed.

Balance Wheels/Rail

- The balance wheel rail is severely corroded and in very poor condition. There is 100% section loss of the web at over ~300mm of the rail. In addition, there are many other small perforations through the web and the fasteners at the joints are severely corroded.
- Excessive clearance between the wheels and the rail was noted at 4 of 6 balance wheels.
- At wheel No. 1, there is a heavy impression in the top of the rail from the wheel indicating that the wheel contacts the rail under live load of traffic. The balance wheels are not intended to carry live load. There are similar impressions at other locations to a lesser extent.
- Wheel Nos. 1, 4 and 5 have a groove worn in to the rolling surface, indicating heavy contact during operation. The depth of the grooves range from .25 mm to .58 mm. The other wheels have negligible wear.
- The balance wheel bearings are inaccessible for clearance measurements. However, clearance can be checked by rocking the wheel. Based on this indirect method of checking, clearances are likely in excess of an ANSI RC6 fit, which is the required fit for bearings per CAN/CSA-S6-06.

East End Caster Wheels/Strike Plates/Skids

- The caster wheel bearings are inaccessible for clearance measurements. However, clearance can be checked by rocking the wheel. Based on this indirect method of checking, clearances are likely in excess of an ANSI RC6 fit, which is the required fit for bearings per CAN/CSA-S6-06.
- The existing end support casters were the same size as the balance wheels and were not sized to take the live load which occurs at the east end of the span.
- The “skids” at the west end of the bridge hit and then bounce/drag across the pier as the bridge swings. There is a groove worn into the west pier due to contact with the southwest skid. This is because the northeast end caster comes into contact with the southeast caster rest as the bridge swings causing the bridge to tip resulting in contact at the opposite end of the bridge.

End Lift Jacks

- The external condition of the end lift jacks was poor. The cylinder bodies are moderately corroded.
- The end lift jacks directly lift the end of the span and are not self locking so that hydraulic pressure must be maintained in the end jacks in order to maintain the load. This arrangement of the end lift jacks does not meet the requirement of CAN/CSA-S6-06 states that “the actuating mechanism shall be non-reversible under the action of the live load.” Failure of the hydraulic piping system (which has occurred previously according to maintenance personnel) would result in failure of the end jacks to support live load. This is a safety concern.

Locking Pin

- The external condition of the locking pin machinery was poor. All components and the structural steel that supports the locking pin were moderately to heavily corroded.
- The design of the locking pin machinery did not provide for energy absorption. When the locking pin engaged, there was an impact load on the locking pin machinery.

Research & Maintenance Feedback

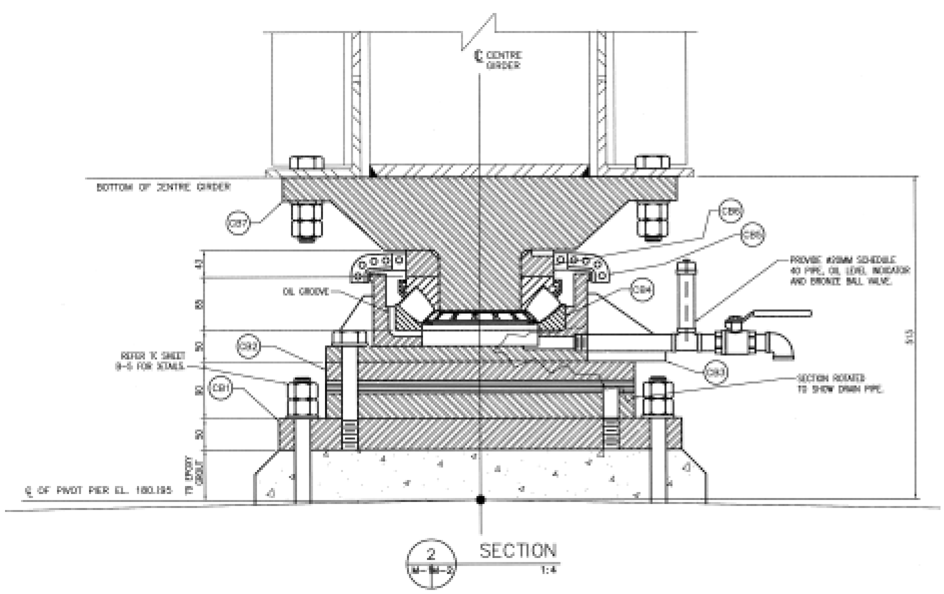
Public Works Government Services Canada operates several other swing bridges over the Trent-Severn Waterway. Two of these bridges, Swing Bridge 44 and Swing Bridge 50 were studied to determine if there were any design improvements that could be implemented in the design of Swing Bridge 60. Swing Bridge 44's hydraulic control system for the span drive cylinder and end lift cylinders was upgraded by Public Works personnel. Swing Bridge 50 was recently replaced and has new structural, mechanical and electrical machinery and was in service for approximately 2 weeks at the time of the visit.

At Swing Bridge 44 it was found that the addition of a counterbalance valve in the swing circuit to provide for braking and variable speed of operation helped with the control of the leaf. At Swing Bridge 50 it was found that the method of supporting the rails on the pier was an effective and efficient solution that provided adequate support and did not retain water or debris.

The maintenance personnel suggested that it would be advantageous to be able to remove the hydraulic cylinders during the winter closure without closing the bridge for roadway traffic. This will allow them to store the hydraulic cylinders in a temperature controlled environment during the winter closure.

Center Bearing

One of the major components of a swing bridge is the center bearing. All of the weight of the swing span is taken by the center bearing when the bridge is open and the swing span pivots about the center bearing. It is important to design the center bearing to be sturdy, requiring minimal maintenance and providing reliable operation for many years.



Sketch 1: Section View of New Center Bearing Assembly.

The highlights of the new center bearing design are as follows:

- The design uses a spherical roller thrust bearing which is sized for the dead load, live load and ice load. The friction the swing span machinery sees as the swing span rotates is less in a spherical roller thrust bearing than a plain bearing. Spherical roller thrust bearings also require less maintenance as compared to plain bearings as they do not require frequent grease application.

- The design of the spherical roller bearing housing was such that it contained the bearing in an oil bath and prevented debris from entering the bearing by using a stainless steel cover.
- Other features of the housing were that the bearing can be shimmed in place at installation, bearing oil can easily be replaced and the bearing can be easily replaced without damage to the housing, if the need arises.
- The floor below the bearing was pitched to prevent water accumulation at the center bearing.

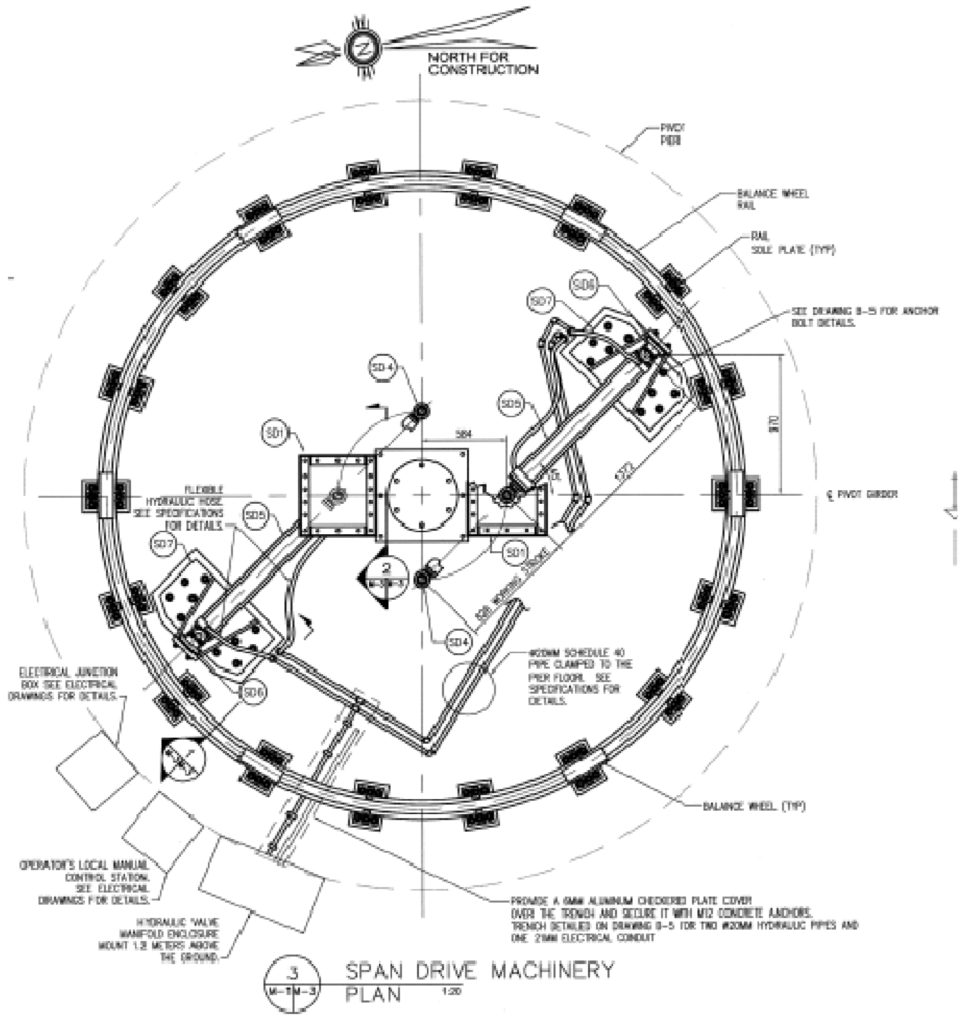
Photo 1: Center Bearing

Span Drive Machinery

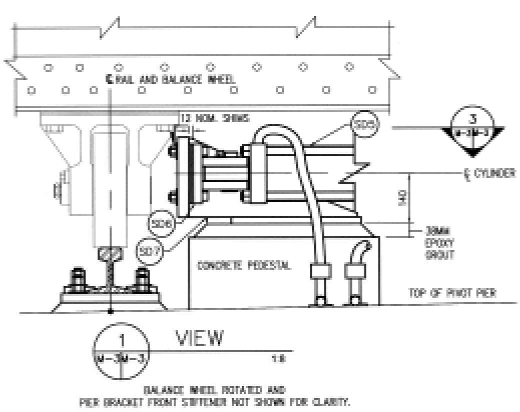
The span is operated by two hydraulic cylinders. The rod end is attached to a bracket mounted to the pivot girder and the blind end is mounted to a bracket anchored to the pier. When these cylinders extend they rotate the span 90 degrees to open the channel. The design of the span drive machinery was generally an in kind replacement of the existing machinery.

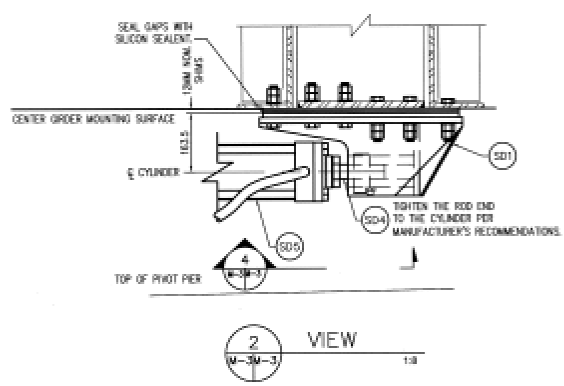
The highlights of the new span drive machinery design are as follows:

- The girder bracket was provided with extra bolts to prevent pack rust development.
- The hydraulic cylinders are provided with spherical rod ends to allow for maximum misalignment capacity.
- The hydraulic lines are hard piping where possible and are mounted on vibration isolating clamps and the hydraulic piping and hardware are made from AISI 316 stainless steel.
- The hydraulic system is sized such that the maximum system pressure under normal operation do not exceed 1000 psi per the requirements of CAN CSA-S6-06.



Sketch 2: Span Drive Machinery





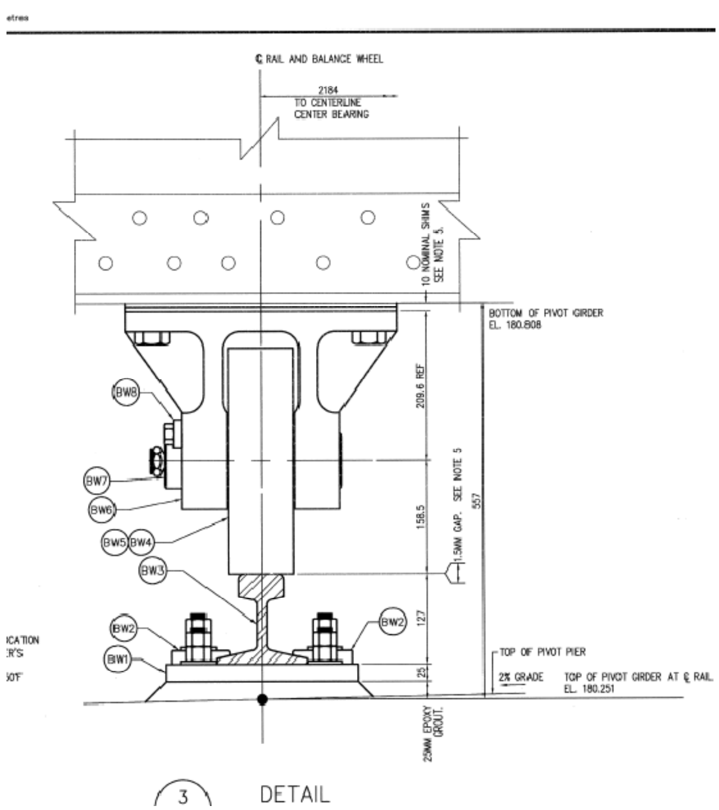
Sketch 3: Span Drive Cylinder Connection Details

Balance Wheels and Rail

The existing span balance wheels and rail were severely deteriorated. The primary reasons for this deterioration were excessive wear due to live loads that the balance wheels and rail were not designed to handle and the accumulation of water and debris that resulted in accelerated corrosion.

To prevent similar deterioration in the future, the following modifications were made:

- The balance wheel clevises were in good condition and were reused in the rehabilitation to decrease costs. To work within this constraint and make the balance wheels stronger, harder materials for the balance wheel bushing and balance wheel were used.
- All components were sized to meet the requirements of CAN CSA-S6-06.
- The balance wheel clevises were modified to provide a keeper plate to prevent the rotation of the pin rather than a set screw that was previously used.
- The balance wheel rail was upsized from 55 lb/yd to 80 lb/yd.
- The balance wheel rail was supported at discrete locations and raised from the pier surface. Also the center pier was pitched to effectively drain water from the pier.



Sketch 4: Balance Wheel Assembly

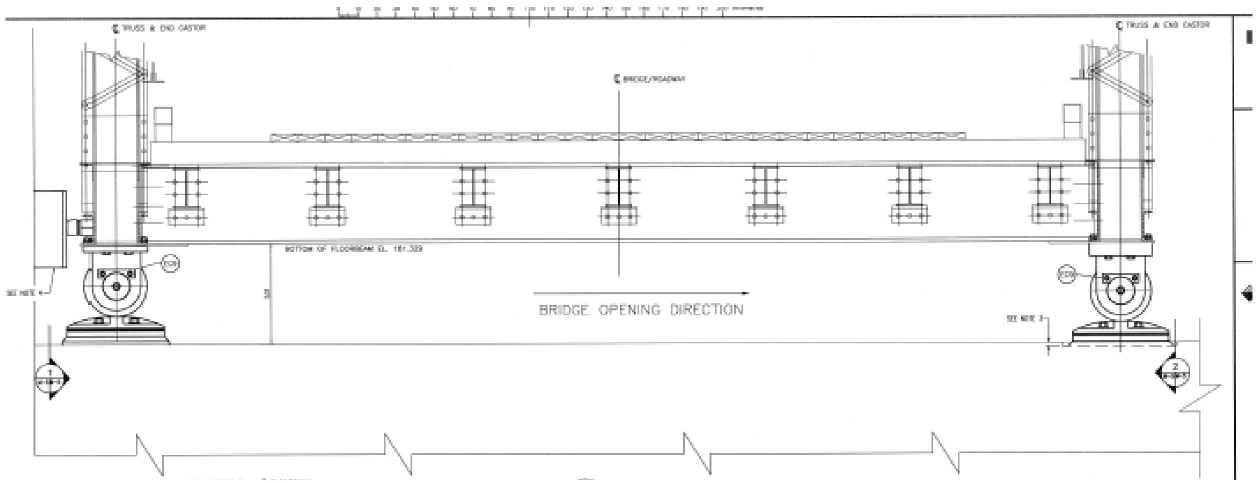
Photo 2: Balance Wheel and Rail

End Support Casters

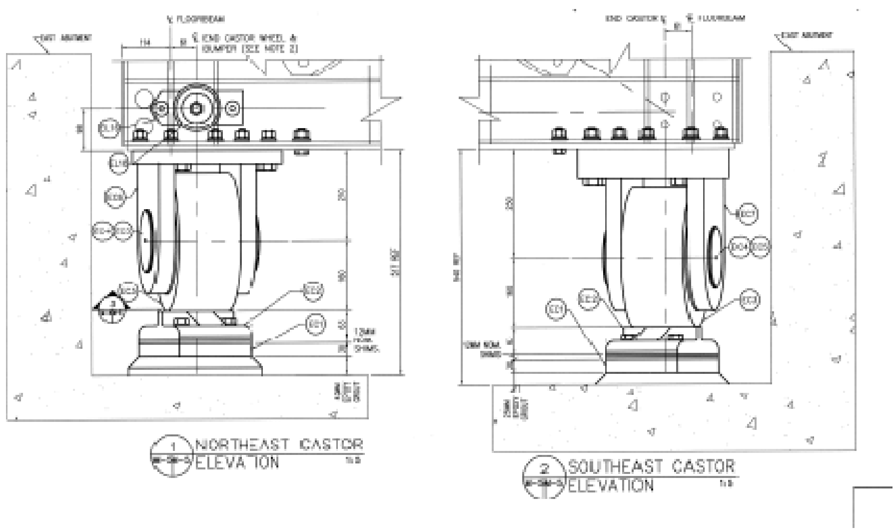
The end support castors on this bridge function such that as the bridge rotates to the channel closed position the east end of the span is supported by the end support castors. Then the span is deflected by the hydraulic jacks located at the west end and the wedges at the west end are driven into position. The hydraulic jacks are then retracted to transfer load from the jacks to the wedges. At this point the span is supported by the end castors, center bearing and wedges. Now the whole span is deflected in the channel closed position allowing the span to take live load at both ends of the span and at the center bearing.

The following modifications were made to the end support castors:

- The width of the castor wheels was increased from 76mm to 145mm. This was done so that the bridge can take the live load as per the requirements of CAN CSA-S6-06.
- The southeast castor was designed to be 40mm lower than the northeast castor. This ensured that as the span rotates the northeast castor can pass over the southeast castor rest plate without contact. This will allow the span to operate smoothly and not bounce due to contact with the rest plate as previously observed.
- Shims are provided under the strike plate instead of above the castor wheel for ease of adjustment.



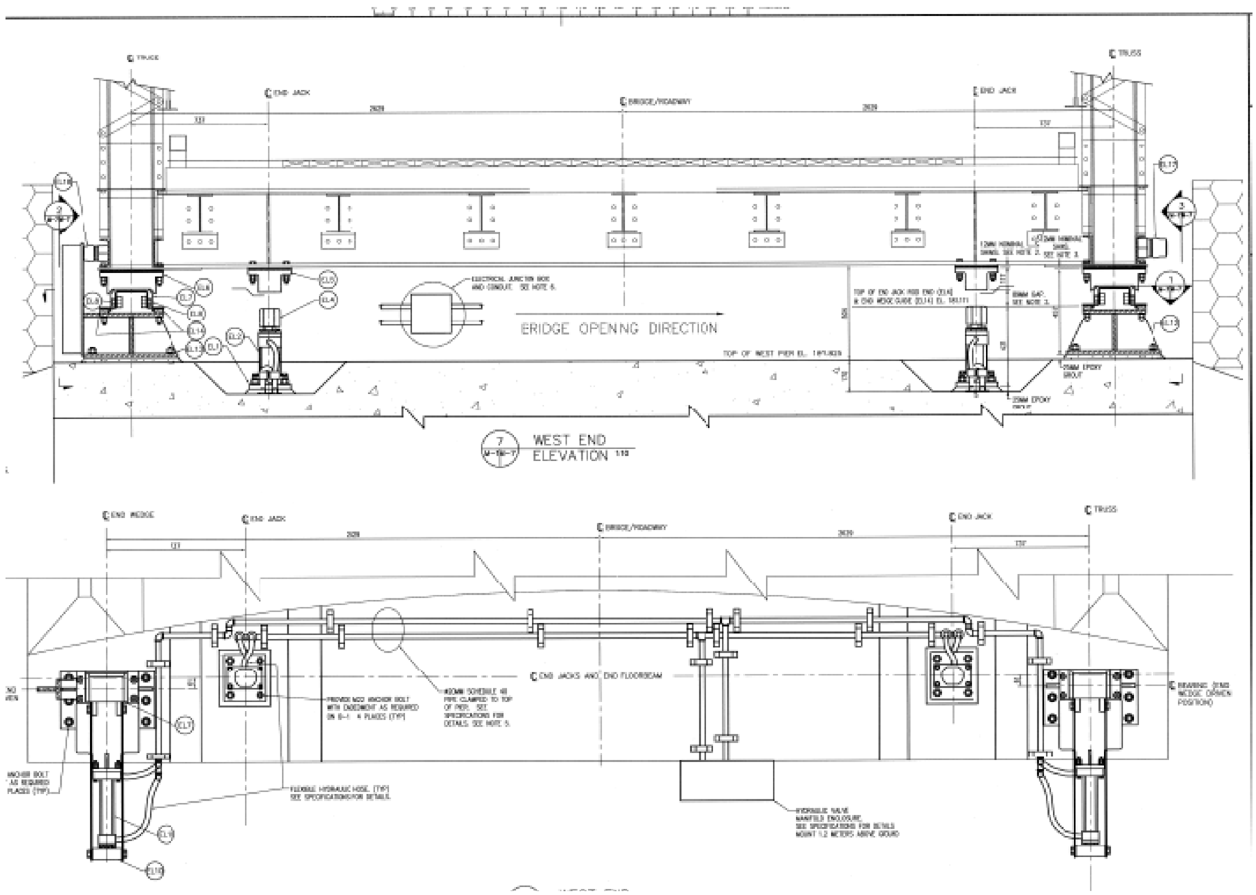
Sketch 5: East Pier Elevation



Sketch 6: East End Castors

End Lift/Support Machinery

The existing end lift/support machinery was a hydraulic jack that raised the span and held it there by maintaining pressure in the cylinder. This did not meet CAN/CSA-S6-06 and therefore a new system was developed where the span is supported on end wedges and hydraulic jacks are used to lift the span temporarily so that end wedges can be inserted or removed.



Sketch 7: West Pier Jacks and Wedges.

The design of the end jacks and end wedges are as follows:

- This arrangement meets the requirement of CAN/CSA-S6-06 and lifts the west end of the span to provide positive reaction by engaging a physical wedge to take the load instead of relying on a pressurized cylinder.
- The hydraulic cylinders are designed to be removable without any impact to the road traffic during the winter channel closure. This will allow for indoor storage of the cylinders in the winter to extend the life of the cylinders.
- The hydraulic lines are hard piping where possible and are mounted on vibration isolating clamps and the hydraulic piping and hardware are made from AISI 316 stainless steel.
- The wedge cylinder is mounted such that the cylinder rod is retracted when the wedge is in the engaged position. This limits exposure of the cylinder rod to the elements to the brief periods when the span is not in the channel closed position.
- The end wedge cylinder to wedge connection bar was made from AISI 316 stainless steel and was designed to cover the cylinder and the end wedge guides. This allowed the connection bar to function as a cover to protect the cylinder and end wedge guides from roadway debris in addition to its function of transmitting force from the cylinder to the end wedge.
- The southwest end wedge support incorporated the strike plate for the end of travel bumper mounted on the span.

- The end wedges are designed so that they will center the span with the approach as the end wedges are engaged. This eliminates the need for a locking pin or other centering devices.

Photo 3: New Installation of the End Jack and End Wedge

Photo 4: New Installation fo the End Jack and End Wedge including the Hydraulic Piping

Energy Absorbing Bumper

The energy absorbing bumpers were installed to stop the span in the event that the span over traveled the limit switches. The channel open position has two bumpers next to each other that engage with the rest pier strike plate. The channel closed position has two bumpers one at the northeast corner and the other at the southwest corner and they engage with the east abutment strike plate and the southwest end wedge support, respectively. These bumpers are sized to take the impact of the span traveling at full speed towards the bumper. The wearing component of the bumper is an elastomeric shape made by Miner and is an off the shelf product. This makes the bumper an efficient design as it is strong enough to take the load and the wearing components are readily available if replacement is necessary.

Photo 5: Energy Absorbing Bumpers at the Channel Open Position

Photo 6: Energy Absorbing Bumper Mounted to the Span

Conclusions

At the start of this project the Port Severn Swing Bridge (Bridge 60) over the Port-Severn waterway in Ontario, Canada was inspected and was determined to be in need of replacement. SBE provided the design and construction services for the mechanical, electrical and hydraulic machinery of this project as a subconsultant to Delcan. The mechanical machinery replacement included the center bearing, the span drive machinery, balance wheel and rail, end support casters, end lift/support machinery and energy absorbing bumpers.

The previous center bearing was contaminated with abrasive contaminants and exhibited heavy corrosion and deterioration. The center bearing was changed to a spherical roller thrust bearing assembly that allowed for shimming during installation, reduced maintenance and the ability to replace the bearing if required.

The span drive machinery was replaced with a new girder bracket with extra bolts to prevent pack rust, and the cylinders were designed not to exceed 1,000 psi operating pressure per the requirements of CAN CSA-S6-06. The hydraulic lines included hard piping mounted on vibration isolating clamps all made of AISI 316 stainless steel.

The previous balance wheels and rail were severely deteriorated with 100% section loss of the web over ~300mm of the rail and heavy wear of the rail and balance wheels. The new balance wheels and rails were designed to meet the requirements of CAN CSA-S6-06. The rail was upsized and was mounted such that there are gaps under the rail and the top surface of the center pier was pitched to allow water to drain effectively. This eliminated areas were moisture and debris accumulated and caused accelerated corrosion.

The existing end support casters were not adequately sized for the live load and the arrangement was such that the northeast castor contacted the southeast rest plate during operation. To correct these issues the end support casters were upsized to take the live load and meet the requirements of CAN CSA-S6-06 and the southeast castor was set lower so that it did not interfere with the northeast castor as the bridge is operated.

The end lift at the west end of the bridge was modified completely. The existing end lift consisted of an end jack that remained pressurized to take the live load. The new design has an end jack as well as end wedges. The new design first jacks the leaf up and then slides the end wedge into or out of engagement. This design allows the hydraulic cylinders to be removed during the winter closure without any impact to the road traffic. The end wedge cover and hydraulic piping are made of stainless steel as they are installed out in the elements.

The locking pin was eliminated from the new bridge design as the end wedges were designed to center the bridge with the approach.

Energy absorbing bumpers were provided to prevent damage to the span in the event of an over travel condition. The wearing component of the bumpers is an elastomeric shape that is an off the shelf product that allows for ease of replacement if needed.

This project involved taking a swing bridge near the end of it’s serviceable life and replacing it with a new bridge with components that meet the requirements of CAN CSA-S6-06. The new bridge design incorporated design improvements in terms of function, ease of installation, ease of maintenance and longevity. Stainless steel components were used where necessary and feasible such as hydraulic piping, piping clamps, and covers. All machinery was studied and upgrades were made wherever necessary and feasible. All of this resulted in a new bridge that meets the CAN CSA-S6-06 code, requires less maintenance and will provide reliable service for many years to come.