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A Unique Vertical Lift Bridge to Replace Newfoundland's Only Movable Span

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Introduction

The New Sir Ambrose Shea Bridge is a tower drive vertical lift bridge that replaced the original Sir Ambrose Shea vertical lift bridge, which was a bare-bones tower-span drive configuration in use since 1961. The bridge is located in the town of Placentia in Newfoundland, Canada and remains the only movable bridge in the province. The town is about 70 miles southwest of the province's capital city, St John's, and has a historic nautical heritage that dates to the 16th century. Fishing is still a large part of the local economy, and fishing boats are the reason for most of the 2,400 yearly bridge lifts.

Figure 1: The New Sir Ambrose Shea bridge (right) standing next to the original Sir Ambrose Shea bridge

The town of Placentia is a popular tourist destination in the summer, and for this reason, an aesthetically pleasing structure which tied into the town's heritage and culture was desired. The area is also known for its windy conditions, with windspeeds often between 20 to 30 mph. Since the town is located on a sandbar low to the water, the wind is salt-laden and extremely corrosive. Winter brings moderate snowfall and the ocean spray causes a heavy amount of ice accretion on the bridge.

The requirements for aesthetics and durability in a harsh environment led to numerous unique design details, and this paper will discuss the structural and mechanical portions of the design.

Design Details

Bridge Type Selection

All three movable bridge types were considered for this location. A vertical lift bridge was favored due to the ability to have a majority of the machinery enclosed high above the water. A swing bridge which provided a large, clear channel devoid of a pier in the center would have been especially difficult and costly. A bascule bridge with below deck machinery would have had trouble providing the long-term durability in such a harsh environment. A bascule bridge with its machinery above the deck would not meet the aesthetics the designers and local people had in mind. Lastly, the original Sir Ambrose Shea was a vertical lift bridge and had become a symbol representing the town.

Bridge Foundations

The town itself is located on two sandbars which the bridge connects. The subsurface conditions for the foundations were therefore silty and poorly graded sand that got looser with depth. No bedrock was found in any of the 70 m (230 ft) boreholes. This required the design of the pier foundations to rely on friction piles or a shallow foundation founded on a competent layer with limited bearing capacity. The contractor was given the choice between the two and chose to build a deep foundation support of friction pipe piles. Close ended pipe piles were chosen because they provide higher skin friction and end bearing compared to H-piles. This option consisted of installation of cofferdams, driving the pipe piles, excavating sub-aqueously down to competent bearing material and pouring tremie concrete, constructing the pile cap on top of the concrete and finishing the rest of the pier construction in the dry.

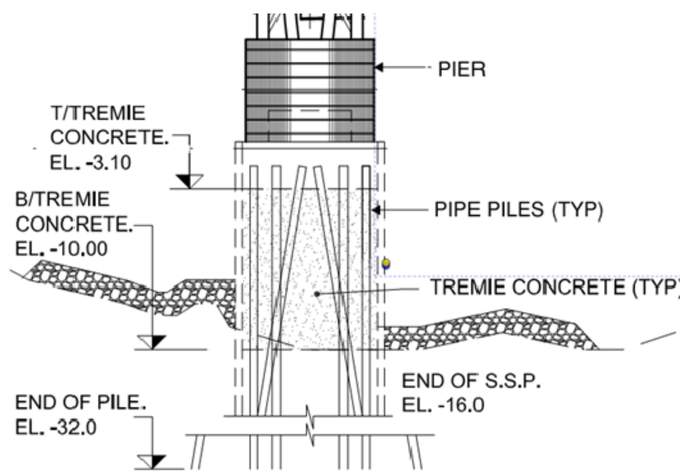

Figure 2: Deep pier foundation option

Towers

The towers consist of a three-dimensional truss shaped to mimic nautical lines. Each tower is connected to the other on the same pier via a three-dimensional exoskeleton truss which also houses the machinery room. The top half of the machinery room is semi-circular and made up of glass panels which give the towers an open, airy feel. Additionally, the visibility of the machinery components and ability to see the sheaves rotating during operation from street level gives a feeling of transparency and familiarity to

Figure 3: Aerial view of one of the towers

passerby.

The tower structural members are comprised of close circular hollow structural sections (HSS) 508 mm in diameter for the main tower legs with the diagonal members ranging in diameter from 168 to 273 mm. The design of the tower's tubular connections is not covered in traditional literature or design codes. Finite element analysis was used extensively for these joints, covering a variety of loading conditions in the open and lowered positions. Additionally, the curvature in the tower legs and braces is unconventional and necessitated detailed specifications and material testing to ensure that material strength and properties were not lost in the bending process.

To give the bridge a more uncluttered and open appearance, the counterweights were designed to hang outside of the roadway envelope and are incorporated into the tower legs. This necessitates using four individual counterweights and makes this bridge one of the few in the world to do so. This is in contrast to a typical tower drive vertical lift bridge where one counterweight hangs centered under each tower, directly over the roadway. The towers on this bridge also accommodate the span and counterweight guides along with a stairway to access the machinery room.

In order to make the structure as durable and weather-resistant as possible, the tower structural members are all sealed structural sections and are metalized and have a two-coat paint system on top. This will ensure extended corrosion protection compared to similar structures.

Machinery

The span drive machinery design for this tower drive bridge is very unusual due to the individual counterweights and their integration into the tower legs. The placement of the counterweights necessitates locating the sheaves in the transverse direction, making it one of the few bridges in the world with this feature. The span drive machinery therefore requires the use of right angle reducers, which are not typically found on tower drive vertical lift bridges.

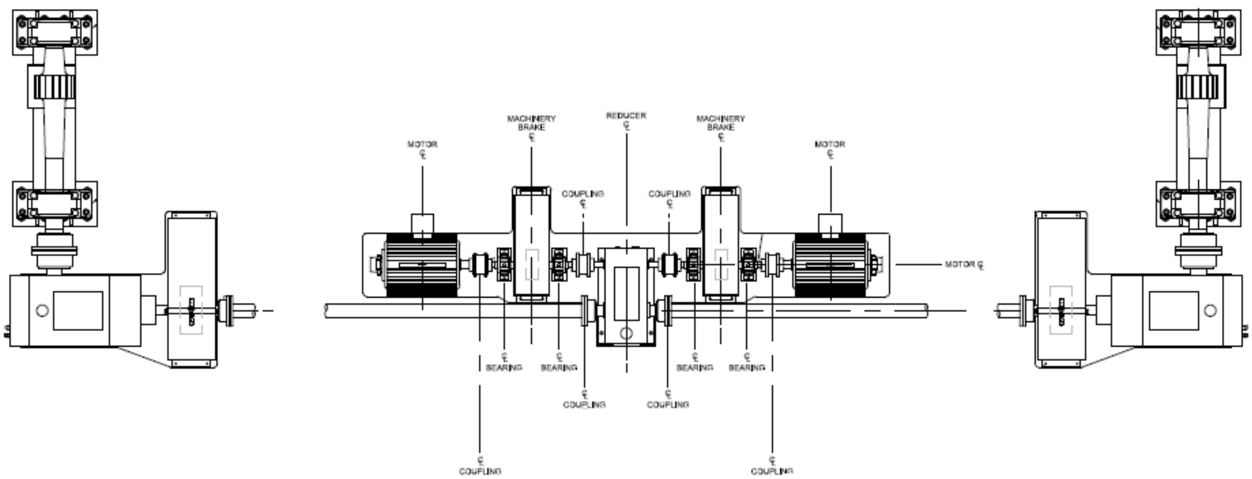

Figure 4: Plan view of the span drive machinery in one tower

The rest of the span drive machinery is fairly typical for new movable bridge construction. There are two motors, each coupled to a simple supported shaft with a motor brake wheel mounted to it. These shafts are coupled to the input shafts of the primary reducer, which outputs to two floating shafts. The floating shafts have couplings with a different number of teeth on each end, to allow for small indexing changes between the sheaves. The floating shafts connect to the inputs of the right angle secondary reducers, which have machinery brake wheels mounted to them. The secondary reducer outputs are coupled to simply supported pinion shafts which drive the ring gears attached to the sheaves. Roller bearings are used throughout the span drive machinery and the sheave trunnions for low friction and all of the machinery is in enclosed rooms protected from the elements. The machinery is all sized larger than required by Canadian Highway Bridge Design Code to allow for the large amount of ice accretion in winter.

The counterweight ropes were designed to have extra spacing between them in order to prevent slapping against each other in the frequently gusty conditions, which was an issue that affected the original bridge. The wire rope strands are galvanized as well

Figure 5: Span drive machinery (primary reducer in center of photo)

Figure 6: Stainless steel span lock housing (with top cover removed)

as the wire rope sockets in order to improve corrosion resistance.

Nearly all mechanical components located outside of the machinery rooms have a galvanized coating if they are steel or are a very corrosion resistant form of bronze for wearing components. The lube fittings on all mechanical components are stainless steel and the span locks located on each pier are completely enclosed in a stainless steel housing. Where there are interfaces between mechanical components and structural steel, it is sealed with a silicone caulk to keep water out. All of these steps were taken to reduce or prevent the onset of corrosion on the mechanical components in one of the harshest environments for a movable bridge.

Conclusions

The New Sir Ambrose Shea vertical lift bridge began construction in March of 2013 and opened to vehicular traffic on September 23, 2016. The total cost of the project was 47.7 million Canadian dollars and included demolition and removal of the old bridge. The new bridge is a visually appealing structure that ties into the area's rich nautical heritage and creates a focal point for the region's tourism industry. The numerous design details to increase the bridge's resilience will go a long way in providing a lengthy service life for a steel structure in one of the most severe climates.