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Ownership/Public Use/Management

Unique Way Of Replacing Main Counterweight Ropes Burlington Canal Lift Bridge Burlington, Ontario, Canada

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INTRODUCTION

The Burlington Canal Lift Bridge is a tower driven steel truss bridge which was constructed in 1962. Between 1962 and 2000 the bridge was raised in excess of 160,000 allowing the safe passage of some 280,000 vessels to and from the Hamilton Harbor. The 2000 tonnes span is 161 m long, and lifts 33.5 m, at a speed of 18m/ min. It was a tight schedule with ten weeks available for construction in a Canadian winter for the replacement of 80 main counterweight wire ropes. The ropes were 57 mm diameter, 6 x 19 classification, 6 x 25 Filler Wire construction with an independent polypropylene core with a minimum ultimate strength of 420 kips.

The bridge provides a vital link between Hamilton Harbour and Lake Ontario through the Burlington Canal for vessels entering Hamilton Harbour and vehicle traffic at 5450 AADT between the cities of Burlington and the Hamilton. The Bridge is operated around the clock, seven days a week, and performs on average 4200 lifts per year

The design and contract administration was carried out by the original designers, Stantec Consulting Ltd (C.C. Parker and Associates) and Parsons Brinckerhoff Quade & Douglas, Inc. Construction work was carried out by Ross Contractors & Engineers of Sarnia, The ropes were manufactured by Briden America. Although not the first wire rope replacement on a lift bridge, this project was by no means routine. Unique problems arose during construction least of which was one of the coldest winter on record, or preparation for a 30 km traffic diversion in the event of bad weather. The contractor used unique yet simple methods to remove and install the ropes, without the use of high cranes or and barges. One consideration was to work on one tower each winter. However, extension over two winters would have multiplied the complexity of traffic diversion and construction costs substantially.

Background

The Burlington Canal Lift Bridge is located on the western shore of Lake Ontario on a site rich history. The bridge spans the Burlington Canal that was opened in 1826.
Once a narrow cut, the canal now provided Burlington Bay at the head of Lake Ontario with navigable access to the Atlantic Ocean. The canal connected the Hamilton Harbour industrial region to international trade and commerce. It was among a series of waterway projects to provide navigation from Lake Erie to the Atlantic Ocean begun 200 years ago. Today, the Burlington Canal remains a busy waterway and is vital to the area commerce.

There were five different movable bridges located on this site since 1830. The present bridge carries four lanes of vehicular traffic across the canal and was opened to traffic in 1962. This structure originally had tracks for the Hamilton-Northwestern railway. The tracks were removed in 1982 when the roadway was widened.

The bridge structure is a tower drive type, vertical lift movable bridge. The lift span is 116 m (380 feet) long, 21 m (65 feet) wide, weighs 2000 tonnes (2200 tons), and has a vertical lift of 33.5 m (110 feet). A system of machinery, sheaves, and wire ropes originating at the towers is used to move the lift span. There is one-150 hp drive motor in each of the two towers to power the machinery and one-150 hp synchro-tie motor in each tower to synchronize the drive motors at each end of the span.

Schedule and Challenges

The Burlington Canal being the only access into the Hamilton Harbour, provides a vital link between the harbour and international shipping. The Harbour remains closed to commercial shipping generally during the period of early January to mid March. In addition to the shipping traffic the bridge carries Provincial Highway 2 (Eastport Drive) linking the cities of Hamilton and Burlington. The main expressway linking the cities is the Queen Elizabeth Way which runs along the high Burlington Skyway Bridge. This bridge provides an alternative to vehicular traffic in the event of the Skyway closure due to high winds or lane closures due to accidents.

The preparatory work including rope fabrication was to take 16 to 24 weeks. Project was awarded in summer to be ready for installation in winter. Several scheduling options were considered, which included;

- Construction during the 10 week winter period when the Bridge is closed to shipping
- Rope fabrication and installation under two separate contracts versus one
- Replacement of one rope at a time
- Replacement of wire ropes on one tower each year (winter construction period)
- Partial lane closure to vehicular traffic and pedestrians
- Total road closure to vehicular traffic and pedestrians

Since the bridge can be closed to shipping only in the winter for about a 10 week period, the discussion was mainly between one or two winter construction periods, and full or partial lane closures. For safety considerations the bridge will be need to be closed to vehicular traffic when the bridge is raised to disconnect and lower the existing ropes, and when the new ropes are being hoisted up. This closure was estimated to add up to several weeks. Night work and vehicular traffic lanes opening and closing was considered too disruptive to the contractors productivity, and confuse the public. It was considered least disruptive to traffic, safe, most cost effective, shortest construction period and better productivity to give the contractor the full bridge for a 10 week period and allow full road closure.

The main concern was to ensure an established contractor with field staff having recent experience in a vertical lift bridge wire rope replacement. Staff resume with reference were required with the bid. The contractor's bids were first evaluated for experience. Only those contractors who met the recent experience requirement were qualified and their bids were opened.

The Bridge site comprised high tension towers on the east side, cable trays on both sides of the Bridge, and tight space conditions. For safety consideration the contractor was determined to use a simpler way to install the wire ropes and not use a high crane or a barge.

ROPE FABRICATON

The wire ropes were manufactured by Bridon America, an ISO 9002 certified company.

The ropes were fabricated at their Oakland City, Indiana plant. As specified the ropes were tensioned initially to 52.5 K which represents 12.5 % of the breaking strength. The rope measurements for length were taken after pre-stretching and with the rope under a tension of 12.5% percent of the nominal breaking strength.

Testing of the ropes took place at the Wilkes-Barre, Pennsylvania facility in accordance with ASTM A 931 (Standard Test method for Tension Testing of Wire Ropes and Strand) The test specimens were taken from the stock of wire ropes for the project. The specimens were as specified: 57 mm (2_-inch) diameter wire ropes preformed 6 x 19 classifications, and 6 x 25 Filler Wire construction with an independent polypropylene core. The project specified a minimum ultimate strength of 420 k. The contract specifications required that the rope slip shall not exceed 1/6 the nominal diameter of the rope (9.5 mm) when the rope stressed to 80 percent of its nominal strength.

The ropes were shipped on 1.8 m (72-inch) diameter reels with appropriate lubrication.

Replacement criteria

Testing of the existing wire ropes in 1999 showed that the ropes had experienced a 14 % loss of breaking strength and 10.5 % loss of metallic area.

AASHTO does not provide specific guidelines relative to rope replacement however in the US two relative codes the ANSI B77 code for tramways has an inspection section. This has been used to determine when tramway ropes should be replaced. The following are criteria from the code.

1. The rope shall have a minimum diameter of 94% of the nominal diameter of the rope.
2. A maximum of six broken wire in all strands and 4 in a single strand shall be allowed in single strand shall be allowed in one lay length.
3. Not more that one third of the diameter of the surface wire shall be worn away.

The ‘Wire Rope Users Manual' published the Wire Rope Technical Board refers to ANSI Standard B30.7 which recommend rope replacement if there were 3 or more broken wires in one strand in one lay.

Alternative for not replacing the wire rope is to wait for rope breakage. In this case the lifting of the Bridge will have to be stopped, or depending on severity of the rope breakage, restrict the frequency of Bridge operation. Burlington Canal is the only shipping channel for access and egress to Hamilton Harbour

Based on the Lloyd's of London, Register of Shipping Code for Lifting Appliances in a Marine Environment and International Standards Association (ISO) 4309 Cranes, Wire Rope, Code of Practice for Examination and Discard, the wire ropes should be changed when the loss of breaking strength and loss of metallic diameter exceeds 10 %. The wire ropes were replaced on the basis of testing that showed 14 % loss of breaking strength and 10.5 % loss of metallic area.

ROPE DESIGN CRITERIA

The existing 80 main counterweight wire ropes were made up of 2 _-inch diameter 6 x 25 filler, improved plow steel, preformed with a sisal core. The original specification called for a maximum rope lay of 6 _ times the nominal rope diameter. The ropes were selected per AREA specification for Movable Railroad Bridges; 1956. Shop drawings indicated a minimum ultimate strength of 425,000 pounds.

A review of the 1953 AREA specifications indicated that the criteria and specifications formulae for rope selection are very similar for allowable direct loading of wire ropes and bending stress. However, the 2000 edition of the AASHTO specifications uses a more conservative method of calculating bending stress. Calculations were performed to check the selected ropes against the applicable specifications. The calculations indicated an overstress of 4 % for bending, using the current specifications. Since the existing sheaves were being used and the groove diameter was sized for 2 _ inch diameter ropes, the selected ropes were 2 _-inch-diameters 6x19 lay with 6x25 filler wire construction fabricated of extra improved plow steel with a fiber core.

ROPES REPLACEMENT

This was the major item of work. The new ropes included all associated accessories such as the rope take-ups, pins, nuts, etc. The possibility of inspecting and keeping the existing rope take-ups were considered, however, limited access and an inability to perform a complete inspection and testing of the take-ups and pins ruled this option out. Moreover, the critical nature of the contract schedule made the project team rather skeptical of risking such critical items.
As is common on most vertical lift bridges built in the 1960s, fatigue of the sheave shafts was not considered during design. Fatigue calculations of the shafts indicated that the shafts did not exhibit an infinite fatigue life as required by 2000 AASHTO. As part of the project work, ultrasonic and dye penetrant testing were conducted.

As part of the rope replacement, the sheave grooves were to be cleaned. The sheave grooves were either corroded or covered with dried and caked grease. The intent was to inspect the sheave grooves for possible damage, as any sharp edges in the grooves could potentially damage the new ropes. The contractor proposed soda ash as a method of cleaning the sheave grooves as the method suggested in the contract documents of using solvents and wire brushes appeared to be labor intensive. After cleaning one sheave it was determined that the soda ash method left white powder on the existing equipment.

WEIGHING THE LIFT SPAN

Over the years, several modifications had been made to the lift span. The bridge had been designed originally as a combined railroad and highway lift bridge. When the railroad was removed, the structural framing was modified. The modification included the addition of a sidewalk and replacement of the deck. Although the modified weight of the lift span had been computed, removal of existing wire ropes and jacking of the counterweights presented an opportunity to weigh the lift span.

DETERMINING BRIDGE IMBALANCE

Strain gage testing of the bridge was done to determine initial imbalance, as well as to bring the bridge to within the specified imbalance. AASHTO Standard Specification for Movable Bridges, Section C1.5.1 in the 2000 edition, specifies a downward reaction of between 1000 and 4,700 pounds at each corner with the span fully seated. This was performed after the rope tensioning. Cement blocks in the counterweight pockets were redistributed to balance the bridge

READJUSTING THE CONTROLLED TORQUE COUPLINGS

Although the readjustment of the controlled torque coupling is typically made as part of any rope replacement on a vertical lift bridge, the couplings were slipping excessively. Consideration was given to replace the couplings, however, complete disassembly of the couplings and, examination of the discs led to the conclusion that the couplings could be rehabilitated. The rehabilitation included cleaning the coupling discs, replacing of the torque springs, and retorquing the coupling bolts.

CONSTRUCTION SCHEME

As part of a feasibility study for the project work, it was anticipated that the removal and installation of the ropes would be accomplished by removal of the sheave shroud and panels from the machinery rooms. Cranes positioned off the approaches or on barges from the canal would then lift the new ropes up the tower. However after several proposed schemes, the contractor used very a simple winch and pulley system to remove the existing and install the new wire ropes. A simple trolley system that attaches to a socket at one end of the rope was used (See figures 1, 2, and 3). To protect the new ropes, each rope was partially covered in plastic tubing. Although the process appeared complicated, the contractor worked very efficiently, increasing the number of ropes installed from about 2 per day to 8 per day there by maintaining the contracts aggressive schedule.

ROPE TENSIONING

The specifications required that the ropes be tensioned following the initial readjustment at one month and six months after the initial tensioning. The specification criterion for acceptance of the rope tension in the main counterweight ropes should not differ by more than +- 5% from the average rope tension at that corner of the lift span.

Following each round of adjustments the bridge was operated through four lifts and the tension rechecked. Any deviation in the tension greater than the 5 % criteria would then be adjusted and the process repeated.

The specifications further required that the rope tension be determined by the use of an accelerometer. While this method is more expensive than the vibration method, the use of an accelerometer produces data that can easily be verified.

ROPE TESTING

In order to demonstrate the strength of the new rope, the specification required that the ropes be tested to meet the minimum breaking strength. The testing was conducted as per ASTM 931 (Standard Test Method for Tension Testing of Wire Ropes and Strand). The minimum breaking strength of the specifications was 420k. The test samples broke at a minimum and maximum of 435k and 445k, respectively.

ROPE LUBRICATION

Lubrication of counterweight ropes is important to the longevity of new or existing ropes. Most lift bridge ropes are maintained by applying lubricants to ropes that are already covered with dry lubricants, forming a type of plastic coating on the wire ropes. Rope dressing that merely covers the surface of the ropes and does not saturate the rope core will not keep the rope in good condition. The lubricant recommended for this project was a “solvent cut back” type lubricant. The lubricant is in liquid state during application and solidifies long after being applied. The use of an automatic lubrication system was considered; however after consideration of several systems, the more traditional method of brushing the lubricant over the wire ropes at the sheaves was maintained.

SEATING OF LIFT SPAN

One of the malfunctions that was expected to be resolved on this project was the proper seating of the lift span. Prior to the project, the lift span was not fully seated at all four corners of the live load shoes. It was anticipated the following could be the cause of the problem:

1. Unequal tension of the main counterweight ropes
2. Bridge imbalance
3. Improper adjustment of the controls torque couplings
4. Indexing of the operating machinery.
5. Improper elevation of the live load shoes

After all the above issues were corrected the bridge was still not fully seated. An investigation of the seating sequence of the lift span indicated that the lift span seats after releasing the brakes. An adjustment of the seating sequence resolved this issue.

CONCLUSION

In spite of the severe cold and time constraints, the project was completed one day ahead of schedule. The cooperation of the project team was key to the success of this project. During the 10 week schedule the communication and meetings between the client, contractor designers and fabricators contributed to the success of this project.

Burlington Canal Lift Bridge

New Ropes Attached at Counterweight

BURLINGTON LIFT BRIDGE SPECIFICATIONS

OWNED AND OPERATED BY PUBLIC WORKS & GOVERNMENT SERVICES CANADA
1157 BEACH BLVD. HAMILTON ONTARIO L8H 6Z9

BURLINGTON CANAL LIFT BRIDGE, TOWER DRIVEN, STEEL TRUSS
LIFTING EQUIPMENT 4 - 150 H.P. WOUND ROTOR MOTORS
POWERED BY 1000 KVA TRANSFORMER AND BACK UP DIESEL GENERATOR
FIRST LIFT JANUARY 1962

LAT. 43' 17.80N LON. 79' 47.69W
ELEVATION TOP OF CONCRETE TOWER BASE 254.75 FEET (77.647 METERS)
CONTROLLED HIGH WATER LEVEL 248.0 FEET (75.59 METERS)

DIMENSIONS

LIFT SPAN LENGTH	380 FEET	(116 METERS)
TOWER SPAN LENGTH	32 FEET	(9.8 METERS)
APPROACH SPAN LENGTH	41.4 FEET	(12.5 METERS)
TOTAL LENGTH	526.8 FEET	(161 METERS)

CLEARANCE

CANAL WIDTH	300 FEET	(91.5 METERS)
ROAD WAY WIDTH	44.5 FEET	(13.6 METERS)
SIDEWALK WIDTH	5 FEET	(1.5 METERS)
ROAD VERTICAL	20 FEET	(6.1 METERS)
ROADWAY TO TOWER FLOOR	160 FEET	(48.8 METERS)
ROADWAY TO SKF BEARINGS	170.5 FEET	(51.9 METERS)
UNDER SOUTH UNDERPASS	11.8 FEET	(3.5 METERS)
PIER TO UNDERSIDE OF SPAN	7.1 FEET	(2.1 METERS)
HEIGHT OF LIFT	110 FEET	(33.5 METERS)
LIFT CLEARANCE	120 FEET	(36.5 METERS)
SEAWAY CLEARANCE IS	116.5 FEET	(35.51 METERS)
MAXIMUM VERTICAL SPEED	60 FEET PER MINUTE	(18.2 METERS)

WEIGHTS

SPAN WEIGHT	2200 TONS	(1995.84 TONNE)
COUNTERWEIGHT, EACH	1093 TONS	(991.57 TONNE)
OUT OF BALANCE LOAD (SPAN)	14 TONS	(12.7 TONNE)