HEAVY MOVABLE STRUCTURES, INC.

NINTH BIENNIAL SYMPOSIUM

"Preserving Traditional Values with New Technologies"

OCTOBER 22 - 25, 2002

VERTICAL LIFT BRIDGE REHABILITATION

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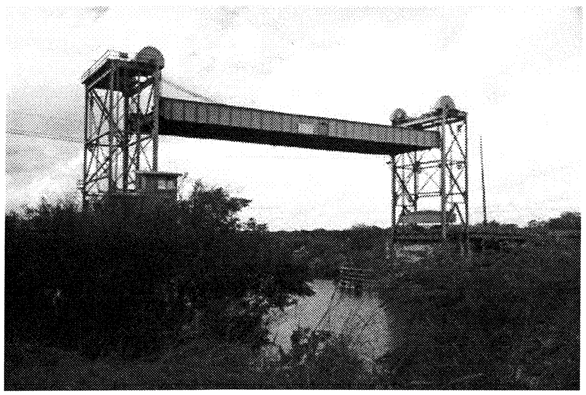
PERFORMANCE/CONSTRUCTION/MAINTENANCE

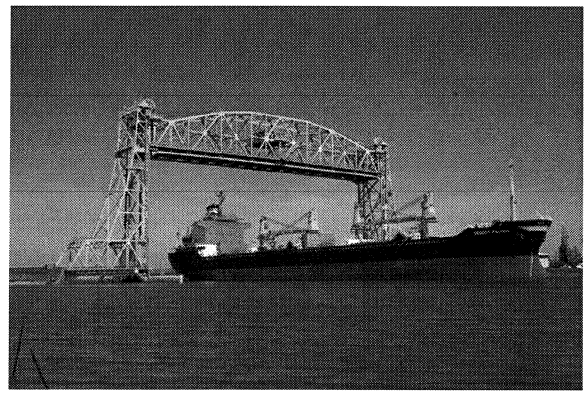
Executive Summary

The following paper is being presented at the HMS Movable Bridge Symposium, October 23-25, 2002, in Daytona, Florida. The paper presents a discussion of several vertical lift bridge inspections, repairs and rehabilitations performed by Harrington & Cortelyou, Inc.

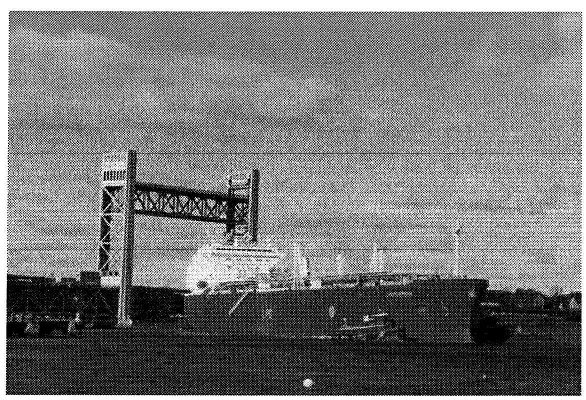
Bridges include:



Rio Hondo Vertical Lift Bridge, Rio Hondo, Texas



Tule Lake Vertical Lift Bridge, Corpus Christi, Texas



Sarah Mildred Long Bridge, Portsmouth, New Hampshire- Kittery, Maine

A general overview of vertical lift bridges is presented, with discussion of electro-mechanical considerations, ropes, sheaves, inspection, repair, and rehabilitation for span drive and tower drive bridges.

Lift Bridge Rehabilitations

The rehabilitation process typically begins with a detailed inspection of the structural, mechanical and/or electrical components of the bridge. The use of pre-prepared forms assures that all relevant components are included and that measurements are recorded in an organized manner.

Inspection findings are evaluated where worn, deteriorated or damaged components are observed. Comparison to previous inspection reports, when available, often provides valuable information related to changed conditions. Recommendations for estimated remaining life, repair or replacement of the various components are typically summarized in report form. Complete structure replacement costs are often evaluated for owner information and long range planning.

When repair or rehabilitation is necessary, plans and specifications are typically developed to AASHTO, AREMA or NEC requirements. Construction may be by contractor or owner forces.

Rio Hondo Lift Bridge

The Rio Hondo lift bridge carries Texas Hwy FM 106 over the Arroyo Colorado at Rio Hondo, Texas. The 145 ft. lift span carries two lanes of traffic and two sidewalks. A full vertical lift of 45'-8" is provided. A tower drive system is used for bridge operation.

When initially inspected in 1996, the lift bridge utilized streetcar type controllers, original motors, drive machinery and an auxiliary gasoline generator. A complete rehabilitation of the bridge was made in 2000, with conversion to fully programmable controls. New motors, brakes, electrical system and bridge ropes were provided. A diesel auxiliary generator was also installed. Inspection of the counterweight ropes revealed significant deterioration in the ropes at the anchorages to the counterweight. Counterweight ropes consisted of six, 1-1/4" diameter, 6x25 filler wire construction with hard fiber core ropes at each of the four corners. Several complete strands had broken due to deterioration, at the northwest corner. **(Figure 1)**

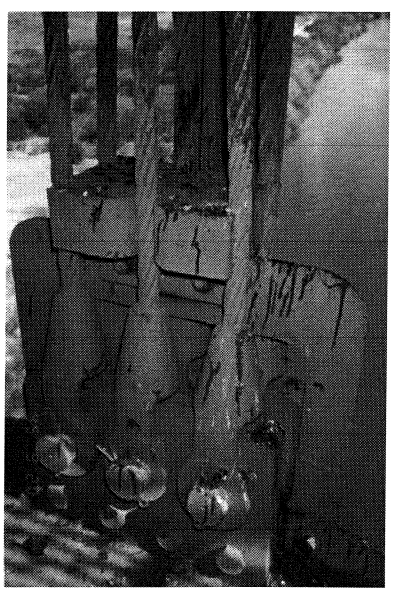


Figure 1

Deteriorated Counterweight Ropes

Further investigation showed significant deterioration to the northwest sheave ring gear located above the deteriorated rope anchorages. Gear teeth were approaching knife edge conditions, with probability of breaking teeth imminent. Problems with the ropes and ring gear are attributed to an extended lack of lubrication early in the life of these components.

Replacement of the northwest ring gear and all counterweight ropes was necessary. Plans for the 9'-0" diameter ring gear were developed for replacement in two halves, to allow the sheave to remain in place. The contractor proposed to remove the sheave and install the ring gear in one piece at the suggestion of the gear manufacturer. A more precise machining and fit up could be provided with the one piece gear.

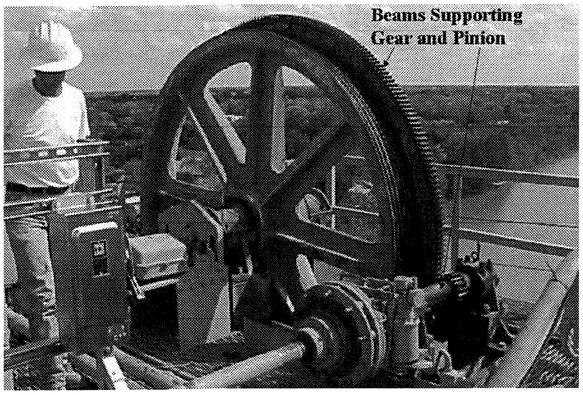


Figure 2

Original Ring Gear

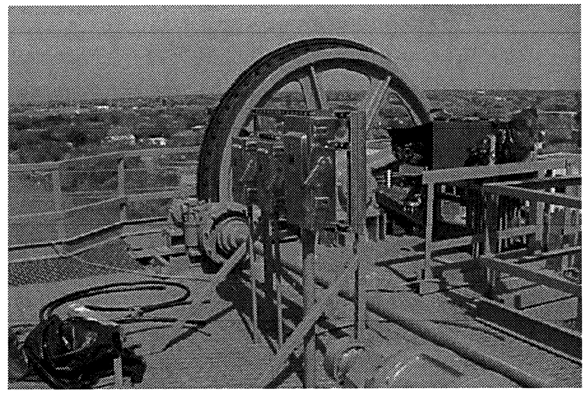


Figure 3

Replacement Ring Gear

After the counterweight was supported from the tower and the bridge ropes were removed, the northwest sheave was removed and transported to the machine shop. The old gear was removed and the new gear installed. **(Figure 2 & 3)** Sheave was returned and reinstalled over a 24 hour period. New ropes were then installed on the bridge.

The 80'-9 ½" ft. ropes were stretched out on the deck prior to installation. Ropes were twisted to achieve proper lengths, then painted with a stripe to assist in rope placement. Ropes were installed and tightened to achieve equal tension in all six ropes at each corner. Turns of nuts at the anchorage were required to increase or decrease tension in each rope.

Rope tension was estimated by lateral displacement of the individual ropes. Displacements were measured for 100 lb. and 500 lb. horizontal pulls at a pre-determined location on the ropes. Rope tensions were computed for the measured displacements. Adjustments to the nuts at the rope anchorages were made to equalize the tension in all six ropes at each corner. Three iterations of measuring tension and adjusting were typically required to equalize the tension in each rope.

The use of vibration analysis to determine rope tension was attempted but was not successful. The rope bridle near the span anchors transferred vibrations to several ropes resulting in non-uniform vibration modes.

Rehabilitation of the bridge included conversion of the electrical system to PLC controlled operation. Span location is monitored by an infra-red laser position indicator mounted to the tower on opposite corners on each end of the bridge. The beam is sent from the tower and reflected vertically off of the sidewalk on the movable span below. Span location is maintained within 6" vertical skew alignment during raising and lowering operations.

Tule Lake Lift Bridge

The Tule Lake Bridge carries Navigation Boulevard over the Tule Lake ship channel in Corpus Christi, Texas. The lift bridge carries highway and railway traffic and spans 344 ft. A full lift height of 129 ft. is provided. The span drive system was completely rehabilitated in 1992. Repairs to the sheaves were also made.

Subsequent inspections have been performed for the Port of Corpus Christi Authority. Several items of interest have been observed. A recent inspection revealed a damaged shaft journal when a bearing cap was removed. While discussing possible reasons for the damage, a workman noted that he had found one of the cap bolts on the floor a couple of weeks prior. Two other bolts were loose, with the remaining bolt still tight. The bolt was reinstalled and all bolts tightened at that time.

After removing the bearing cap, damage observed at the 5" diameter shaft included a 1¾" wide x 1/8" deep missing piece of the steel shaft. **(Figure 4)** The damaged area extended circumferentially over half of the visible journal, with the remaining 1 ¾" wide portion somewhat loose. The total width of the shaft in the bearing is 9".

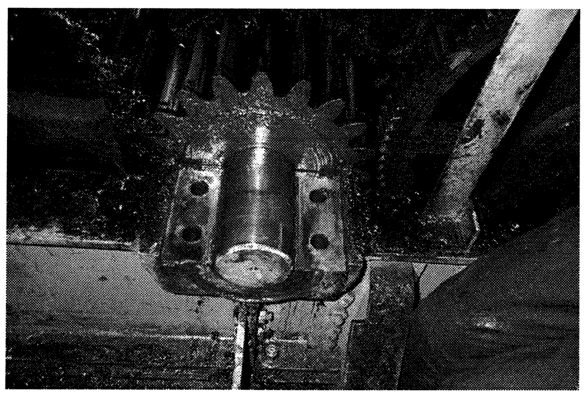


Figure 4

Damaged Shaft

A replacement shaft is currently being machined. In order to minimize bridge down time at the busy port, repair of the existing shaft was not desirable due to the length of time required for transporting the shaft and making the repair. A new shaft and gear assembly will replace the existing gear and damaged shaft. Minimal bridge closure to navigation traffic was deemed a top priority by the owner. All cap nuts and bolt stick-thrus are being painted with a vertical stripe. As bridge maintenance crews lubricate the bearings, they also now look for possible loose nuts by checking the alignment of the nuts.

During an inspection of the sheaves, cracks were detected along the centerline of the sheave. Original sheaves were constructed in two halves. Cracking was detected along the weld where the two halves were connected. To avoid the high cost of replacing the sheaves, a repair was developed to strengthen the sheaves, after the cracks were repaired.

Steel pipe struts, extending radially from the hub, were inserted between the existing spokes. Welded shim plates were used to develop a tight fit to the hub and outer portions of the sheaves. The struts reduce localized deflections as the sheaves turn and the counterweight ropes load the sheaves. **(Figure 5)**

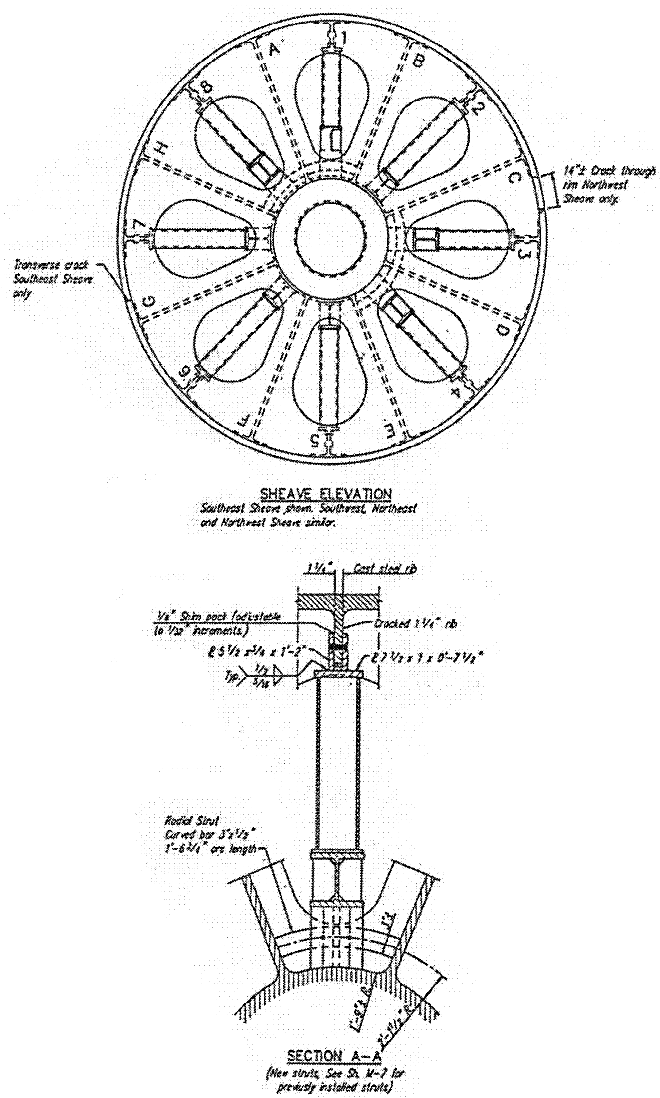


Figure 5

Sheave Reinforcement

Sarah Mildred Long Bridge

The Sarah Mildred Long Bridge carries Route 1 and the Boston & Maine Railroad between Portsmouth, New Hampshire and Kittery, Maine. A two-lane highway occupies the upper level of the bridge with the single track railway on the lower level. Span operation of the 224 ft. span is by tower drive machinery. A full vertical lift of 125 ft. is provided.

A number of inspections have been made over the years. A major rehabilitation, including conversion to PLC controls was performed in 1992.

Recent modifications to the bridge include the addition of traffic barriers, auxiliary generator and closed circuit television (CCTV) cameras in 2001.

Routine inspections of the bridge include non-destructive testing of the sheave shafts. Dye-penetrant testing of the fillet on the shaft is performed. **(Figure 6)** Sheaves are rotated through 120 degrees of rotation with shafts observed and tested at each location.

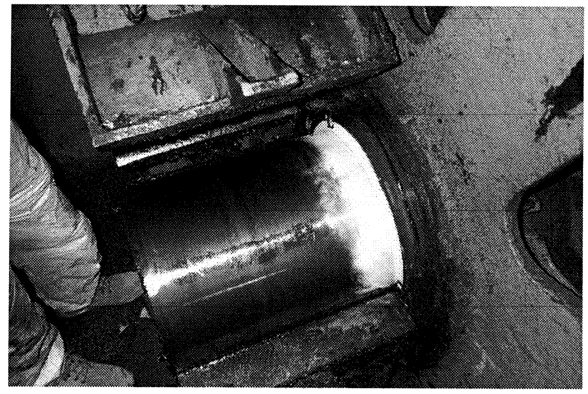


Figure 6

Dye-Penetrant Testing on Sheave Shaft Fillet

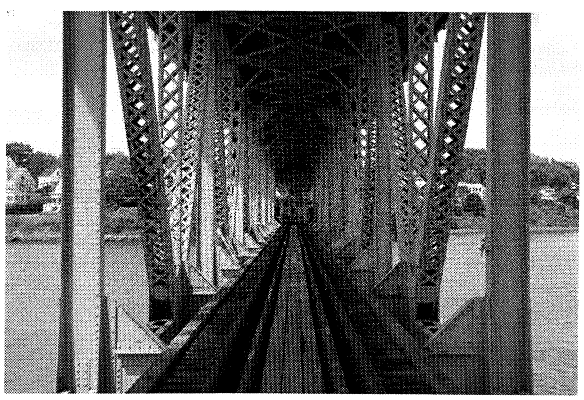


Figure 7

Retractable Railroad Span

An interesting modification was made to the bridge in 1965. The lower level of the bridge carries rail traffic. Trains use the bridge on the order of twice per month. It was determined that frequent lift span openings were being required for small pleasure craft, in addition to the high volume of lifts required for large commercial ship traffic.

One fixed side span of the lower level railroad was converted to a retractable span. Screw jacks were added to raise the lower portion of the span. Railroad wheels, axles and mechanical equipment were added to translate the span along the rail line into the adjacent span. **(Figure 7)**

This span now remains in the open position at all times until a closure is needed for train traffic. A 40 ft. vertical clear opening is now provided for small pleasure craft, 450 ft. away from the main navigation channel.