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Revitalizing 100 Year Old Movable Railroad Bridges

Revalorisation d'anciens ponts ferroviaires mobiles

Ertüchtigung 100jähriger beweglicher Eisenbahnbrücken

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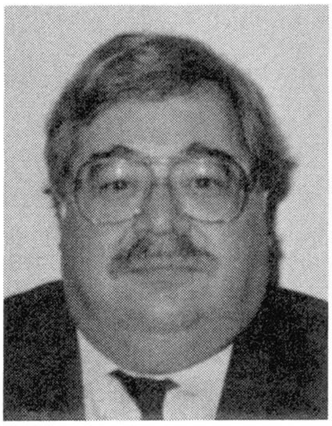

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SUMMARY

Three major movable bridges, two rolling lifts and one swing span, on a four track catenary powered railroad, constructed in the late 1800's, were in need of extensive rehabilitation to continue to provide reliable service. This paper describes the design and construction methods used to accomplish the upgrading of the structural, mechanical, and electrical systems within the restrictive confines of an operating railroad and active navigational channels. The use of modern design, fabrication, and construction technology revitalized these 100 year old structures.

RESUME

Trois ponts mobiles importants – deux ponts roulants et un pont à bascule – situés sur une ligne de chemin de fer alimenté par quatre caténaires de voie, tous construits vers la fin du siècle dernier devaient être rénovés afin de continuer à assurer leur service. Cet article présente les études et les méthodes de construction adoptées pour moderniser les systèmes structuraux, mécaniques et électriques dans les limites restrictives d'une voie ferrée de service et de canaux de navigation en activité. Le recours à des techniques modernes de calcul, de fabrication et de montage ont permis de revaloriser ces ouvrages datant de plus de 100 ans.

ZUSAMMENFASSUNG

Drei grössere bewegliche Brücken – zwei Hubbrücken und eine Drehbrücke – auf einer vierspurigen, kettenangetriebenen Eisenbahnlinie stammen aus dem späten 19. Jahrhundert und bedurften einer umfangreichen Ertüchtigung für die weitere zuverlässige Nutzung. Der Aufsatz beschreibt den Entwurf und das Vorgehen beim Umbau der tragenden, mechanischen und elektrischen Systeme unter fortlaufendem Eisenbahn- und Schiffsverkehr. Moderne Technik, Fertigung und Montage verhalfen den 100 Jahre alten Bauwerken zu neuem Leben.

INTRODUCTION

Metro-North Commuter Railroad's New Haven line is a four track catenary powered rail line carrying New York - New Haven commuter traffic and AMTRAK's Washington-New York-Boston service thru Connecticut. The river crossings on the line are movable bridges built in the late 1800's. A.G. LICHTENSTEIN AND ASSOCIATES, INC. (AGLAS) was engaged to perform an in-depth inspection, analysis, design and inspection of construction for the rehabilitation of the structural, electrical, and mechanical systems of three movable bridges:

- Cos Cob Bridge over the Mianus River - twin two-track Scherzer rolling lift bascule deck girder bridges.
- Walk Bridge over the Norwalk River - a four-track rim bearing deck truss 200' span swing bridge.
- Devon Bridge over Housatonic River - twin two-track Scherzer rolling lift bascule thru truss bridges.

AGLAS engineers conducted an in-depth, hands-on inspection of the structural, mechanical, and electrical systems to establish the physical condition of the elements. The program included measuring deterioration of structural members, materials sampling, non-destructive testing, review of bridge operation, evaluation of wear on mechanical components, and evaluation of wiring and electrical equipment.

Following the in-depth inspection, the structural, mechanical and electrical elements were evaluated. The rehabilitation of the structural steel was geared toward strengthening the existing members or replacing deteriorated components rather than replacing entire members. Many of the mechanical components were suitable for reconditioning rather than replacement. The electrical systems were obsolete, and replacement was necessary.

The deteriorated conditions and the construction methods used to accomplish the revitalization of these three complex structures while maintaining high-volume rail traffic are described herein.

COS COB BRIDGE OVER MIANUS RIVER - COS COB, CONNECTICUT

The original main drive operating system of the twin, deck girder, Scherzer Bascule Bridges consisted of electric motors located on the Operator's House structure, and a lengthy configuration of shafts, couplings and gears running to a rack and pinion located at the centerline of each bascule. The rack is attached to an operating strut pinned to the centroid of the bascule. Rotation of the pinion pulls the operating strut horizontally, rolling the segmental girders of the bascule on the track girders and lifting the span.

The long gearing and shaft system, which included a bevel gear set, had proven to be very inefficient. Inspection revealed that the shaft bearings for the main drive system exhibited excessive clearances, while the gears were only slightly worn. Excessive wear was present at the shaft bearings of the toe and heel lock systems. Lubrication of the machinery had been neglected at several locations where access was difficult.

The original electrical system, built to be powered by a 25 cycle source, had been obsolete since the railroad generating plant ceased to operate. As a temporary measure, motor/generator sets had been installed on the bridge to take standard 60 cycle power from a public source and convert it to 25 cycle power. The electrical system was in generally poor condition, and it was increasingly difficult to find spare parts for the 25 cycle equipment.

The in-depth inspection of the structural steel revealed: severe bottom flange deterioration of track girders and supporting girders, due to spray from the choppy salt water hitting the piers; worn lugs and pockets of the track and segmental girder tread plates, which permitted slippage and misalignment of the bascules as they operated; severe deterioration of steel housing the counterweights; and cracks in the track girder tread plates and their connecting angles. By current design criteria for railway bridges (A.R.E.A.) the tread plate and web thicknesses of the track and segmental girders were inadequate to support the rolling load of the bascule.

Evaluation of the structure produced a rehabilitation scheme that would include: elimination of much of the machinery by placing new motors under the span adjacent to the bascule heel; reconditioning machinery that would remain; replacement of the electrical equipment with a solid state, computer controlled, 60 cycle system; installation of additional side plates and new tread plates on the segmental girders; replacement of the track girders and repair of the supporting girders and counterweights.

The extensive repair work required that the two bascule bridges be inoperative for a three to four month period. The bridges were scheduled for rehabilitation in the closed position during the winter months, when the navigation restriction would have minimal impact. Disruptions to railroad operation were limited to single track outages, and brief periods of double track outage for jacking of the bascule spans.

To permit rehabilitation of the segmental girders and replacement of the track girders, two temporary supports were erected below the existing cross girder. Hydraulic jacks were connected, through a manifold, to an electrically operated pump. Dead load was transferred to the temporary supports by lifting the bascule span 13 mm±, shimming between the cross girder and supports, and lowering the span. This operation was conducted during a two hour period of double track outage. The heel locks were shimmed 1.6 mm to develop full bearing.

Removal and replacement of the track girders and the outer 0.533 m of the segmental girders and repair of the support girders then proceeded. Rehabilitation of a segmental girder involved: removing the existing 51 mm thick tread plate, web stiffener angles and side plates; cutting off and replacing the outer 0.483 m of the circular web; and drilling new holes in the upper portion of the existing web to fasten new, deeper web side plates. The new 127 mm thick tread plates of the track and segmental girders had 51 mm deep, interlocking lugs and pockets. As it would not be permissible to jack up the bascule 51 mm, the segments of track and segmental treads that engage when the bridge is in the closed position were mated and lifted into position together.

To rehabilitate the steel housing the counterweights, it was necessary to remove the counterweight blocks. Each counterweight consists of 285± cast iron blocks, ranging between 1335 N and 20.47 kN. The blocks were lifted out and placed on a track mounted cart that transported them to a storage area.

New machinery and maintenance platforms were suspended from the deck girder span adjacent to the heel of the bascule. The existing main drive machinery that was to remain, as well as the toe and heel lock machinery, was disassembled and reconditioned. To permit disassembly of the toe locks, the toe end of the bascule was temporarily anchored with threaded rods coupled to existing lock pin anchor bolts. A temporary strut was installed in place of each heel lock arm.

The pin assembly and the guide roller and support roller assemblies of the operating strut were replaced. Shafts and shaft couplings for the toe lock drive were also replaced. The bearing journals of the shafts were reground. Shaft bearings were rebored and received new bushings and grease fittings. The heel lock arms received new grease fittings and cast steel fillers. The machinery was reassembled in the field using new turned bolts. New air buffers were installed. New motors and motor mounted pinions and brakes were installed for the main drive system. New gearmotors were installed for the toe and heel locks.

New motor control equipment and a computerized control panel were installed in the Operator's House. The control panel monitors and displays on a screen the entire sequence of operations. If a malfunction occurs, the control system stops operations and identifies the inoperative component. If desired, the bridge operations may be controlled manually from the control panel or from a portable keyboard and screen when plugged into jacks provided at the main drive, toe lock and heel lock machinery.

DEVON BRIDGE OVER HOUSATON RIVER - DEVON, CONNECTICUT

An In-Depth inspection of the twin thru-truss Scherzer Bascule Bridges revealed these serious deficiencies: cracks in the angles connecting tread plates of segmental girders and track girders; the drive pinions had come into bearing contact with the racks, causing the pinion shafts to bend; severe deterioration of end floorbeams, end brackets, floorbeam hangers at track level and of the machinery platform floor system; and significant toe heavy imbalance of the bridges. Additionally, major reconditioning of the main drive and toe lock machinery was necessary to correct the effects of wear. The track and segmental girder web plates and side plates were too thin for the bearing forces exerted by the rolling load of the bascule.

Extensive repairs to the segmental and track girders required that each bascule bridge be inoperative for a two to three month period. To minimize restrictions to marine and rail traffic, the bascules were repaired one at a time. Most of the work was performed with the bascule held by temporary struts in the fully open position. Rail traffic was handled by the two tracks on the twin bascule. Marine traffic was restricted only during repair of the rear segment of track and segmental girders. During this phase of repair, opening of the bascule span required 24 hours advance notice.

The Contractor used two track mounted hydraulic cranes to perform the work. A 267 kN crane, positioned on the track girder span, erected the temporary struts and handled removal and replacement of structural steel and machinery.

The tread plates and outermost side plates were removed from the track and segmental girders. New side plates were added. Removal of the existing tread plates revealed that the bearing edge of the existing web and side plates was worn as much as 9.5 mm. Using the newly installed side plates as a guide, the existing plates were built up with weld metal and ground smooth to develop a uniform bearing surface. The original intention was to re-use the existing tread plates. When they were removed however, inspection revealed cracks on the interior face, and wear of up to 3.2 mm at the surface mated to the web and side plates. New tread plates were fabricated and installed with new connection angles.

The new segmental girder tread plates were fully bolted into place. The new track girder tread plates were only partially secured with bolts for the bascule to be test operated. During the test runs, the lugs of the track girder tread plates were aligned with the pockets of the segmental girder tread plates; and the toe end of the bascule was aligned with the bearings. The first test closure of the bascule produced a 19 mm misalignment of the toe end. The alignment was corrected by a slight longitudinal adjustment of the tread plates on one side of the bascule.

The main drive and toe lock machinery was completely disassembled and reconditioned while the bascule span was strutted in the open position. The pinion shafts were replaced. They had been bent as a result of the wearing of the mating surfaces of the track and segmental girder web plates and tread plates. The wearing had effectively lowered the bascule span and brought the drive pinions into bearing contact with the racks. A cracked differential assembly frame for the south bascule and a section of the main drive shaft of each bascule were also replaced.

The rack support beams were replaced and the racks adjusted to provide proper clearance with the pinions. The bearing journals of the shafts were reground. Shaft bearings received new bushings and grease fittings. Pinions, reduction gears and bearings were rebored to a true cylindrical bore. The gear keyways were recut and fitted with new keys. The machinery was reassembled in the field using new turned bolts. While machinery reconditioning was in progress, the machinery platform members were replaced or repaired with bolted plates and angles.

The worn contact areas of toe lock hooks were built up with weld metal and reground. New grease fittings were attached. The contract drawings provided alternative details for replacement and for reconditioning of the air buffers. After disassembly of the existing buffers, an inspection revealed that they were reconditionable. The inside cylindrical surface was honed to remove degradation; new piston rod assemblies, piston rings, piping and pressure regulating valves were installed. New strike plates were bolted to the pier seat.

Steel repairs were made to return the structure to a Cooper E 72 load capacity. Deteriorated floorbeam hangers were reinforced with steel plates fastened with high strength bolts in existing rivet holes and some new field drilled holes. End floorbeams and end brackets, deteriorated by de-icing salt used at the floor breaks, were seriously deteriorated. The top flange of floorbeams was replaced. End brackets at the heel end were replaced, those at the toe end were reinforced. Structural repairs to the eyebar truss approach spans were made during the double track outage afforded by the bascule rehabilitation.

At the completion of repair work, the bascule spans were rebalanced. Strain gages were placed on the pinion shafts. Strain readings were recorded and torque in the shafts computed for the full operating cycle of the bascule. Computations were made to determine the center of gravity of the span. Based on the torque values and center of gravity computations, counterweight blocks were relocated and additional weights were added to yield optimum balance during operation.

WALK BRIDGE OVER NORWALK RIVER - NORWALK, CONNECTICUT

Operational problems developed with this Railroad Swing Bridge, and became a major concern to the owner. Deformed rollers and worn tread plates, on which this rim bearing swing span is supported, became unreliable and unrepairable. Obsolete motors and electrical equipment added to the uncertainty of the system. Several structural elements of the Swing Span required major rehabilitation.

After a thorough inspection and evaluation of structural, mechanical and electrical components, it was decided to replace all 90 steel roller wheels, and the upper and lower tread plates with new components of higher strength materials. Some shafts and gearing would also be replaced; most of the machinery would be reconditioned. A solid state, computer controlled, electrical system would take the place of the existing equipment.

The extensive repairs required that the swing span be inoperative for a one to two month period. A system was developed to jack and shore the 8900 kN ton deck truss swing span to permit replacement of the roller wheels and tread plates while maintaining Railroad operations. It was necessary to reinforce some of the existing swing span support girders at shoring points. The work was scheduled during April and May, when the navigation restriction would have minimal impact.

Timber and steel cribbing was erected at six locations on the pivot pier. At each location, a group of jacks was connected, through a manifold, to an electrically operated hydraulic pump. To prevent overjacking at any jacking location, each pump had a relief valve set at 150% of the expected load. During a four hour period of track outage, in the early hours of a Saturday morning, the span was lifted and shimmed 9.5 mm. The wedges at both ends of the span were shimmed to develop full bearing. Railroad crews adjusted the rail profile by shimming under the rail plates for a distance of 50'± on both sides of the span. The roller wheels, tread plates and ring gear were removed. The new bottom tread plate/ring gear assemblies were set to grade and to radius measured from the center of rotation. The new upper tread plate was bolted to the drum girder. The 90 roller wheels and connecting bars were then installed. The roller wheel axles were threaded to permit radial adjustment of the wheels.

The vertical drive shaft assemblies, consisting of the shaft, bevel gear, pinion gear and bearings; and the main horizontal drive shaft assembly, were taken to the Contractor's shop. One of the vertical shafts, bent by attempts to operate the span when the wheels were iced up, was replaced. The bearing journals of the other shafts were reground. Pinion gears were replaced. Shaft bearings received new bushings and grease fittings. The machinery was then reassembled in the field using new turned bolts. New motors, motor mounted brakes and pinions, reduction gears and motor supports were installed.

A new centering device was installed at each end of the span. Each new device consists of a motor operated, tapered, vertical, centering pin that is driven down through a pair of rollers mounted on the pier.

The shafts, bearings and linkages of the wedge drive and rail lifter systems were disassembled and reconditioned in the same manner as the main drive system. New motor assemblies were installed.

New motor control equipment was installed in a new room. The computerized control panel, installed in the Operator's House, controls and monitors the entire sequence of operations. In the event of a malfunction, the control system immediately stops operations and identifies the inoperative component. The bridge operations may be controlled manually if desired. New submarine cables were placed in a riverbottom trench between the Operator's House and pivot pier.

Most of the structural repair work, such as replacement of flange angles of truss members and stringers; and replacement of bracing members, was conducted during single track outage. Replacement of expansion bearings for the approach span trusses was performed with the tracks in service, supported by shoring. Replacement of the swing span end floorbeams and end brackets, required a two week double track outage. Major structural/mechanical/electrical components were moved by a rail mounted hydraulic crane. Other materials were transported manually or with the aid of a boat and chain hoists.

Through the use of modern engineering design and construction techniques, these three aged movable bridges were restored to full operation and revitalized for continued service. The $16,000,000 construction project took two years to complete.