Heavy Movable Structures, Inc.

SEVENTH BIENNIAL SYMPOSIUM

November 4 - 6, 1998

Grosvenor Resort
Walt Disney World Village
Lake Buena Vista, Florida

"Repairs to a Scherzer Rolling Lift Bridge"

by

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REPAIRS TO A SCHERZER ROLLING LIFT BRIDGE

Client: AMTRAK

Designers: HARDESTY & HANOVER, LLP

Contractors: CIANBRO CORPORATION

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I PROJECT BACKGROUND

I A - Bridge Specifications -

The Rolling Lift Bridge over the Connecticut River in Old Saybrook, Connecticut is a two track rail structure built in 1907 as a part of the Northeast Corridor, and is still the busiest rail corridor in the country. (See Figure 1) It was designed in 1905 for the Shore Line Division of the N.Y.N.H .& H.R.R. Co. by the Scherzer Rolling Lift Bridge Co. of Chicago and bears many trademarks of its type. The structure is now owned and operated by AMTRAK and heavily used for both passenger and freight rail traffic. The span is 161 feet, providing a 137.5 feet navigable channel when raised.

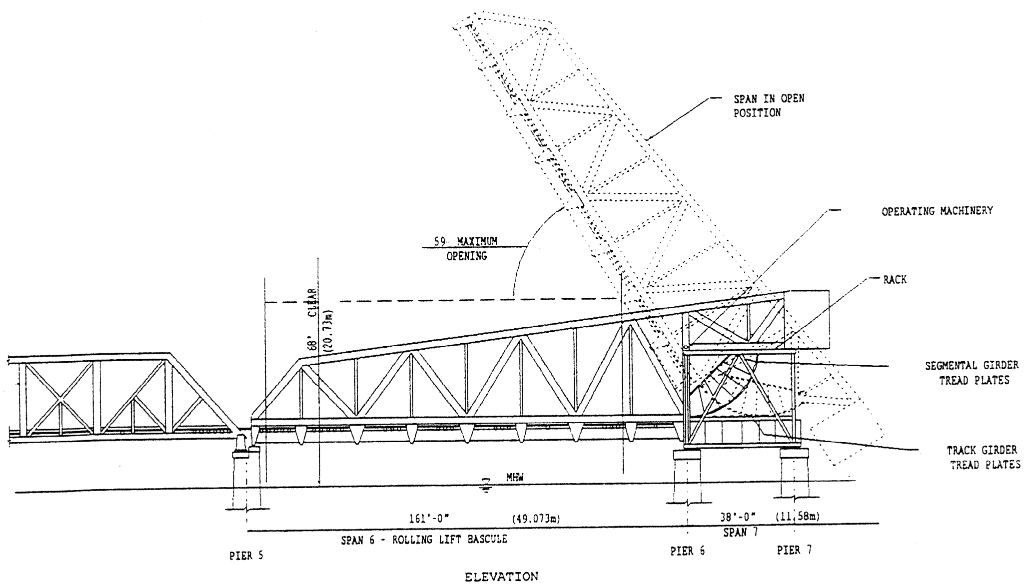

Figure 1 - Elevation of Rolling Lift Bascule Bridge over the Connecticut River

I B - Rolling Lift Description-

The basic concept of a rolling lift bridge is similar to a more traditional bascule bridge, however in this type, the center of gravity of the moving leaf, is allowed to translate horizontally, while the curved bottom plate of the main bascule girder, the segmental girder, rolls back on flat tread plates secured to the substructure. (See figure 2) The tread plates are aligned to each other by means of lugs on the bottom flat plate which key into pockets on the upper segmental plate. These lugs also supply resistance to lateral forces during the roll.

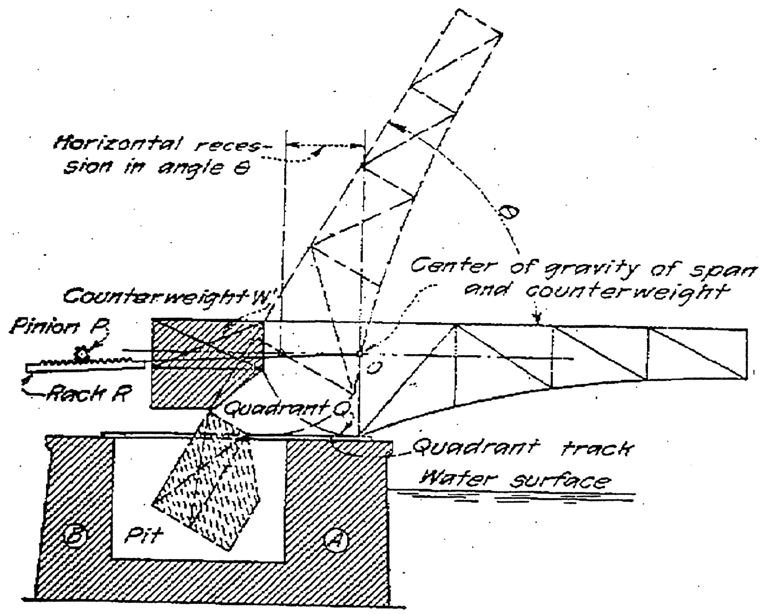

Figure 2 - Typical Section through a Rolling Lift Bascule Bridge
(Reproduced from <u>Movable and Long Span Bridges</u>, Hoole and Kinne)

I C - General Problems -

Over the years of heavy use for rail traffic, the Old Saybrook bridge was subject to the problems inherent to many rolling lift bascule bridges. 'Walking' of the leaf on the track created high bearing stresses resulting in deformations and damage to the lugs and pockets on segmental and track girder tread plates. Wear to the tread plates as well as misalignment of the existing rack segments have systematically damaged the operating machinery to a point where emergency repair was required.

II EXISTING PROBLEMS & DESIGN CONSIDERATIONS

II A - Tread plates -

Upon inspection, the tread plates were excessively worn with numerous cracks, especially at the lug pockets. During span operation, the lugs had periodically been pulled out of the flat tread plate. The lugs were originally mounted by use of a press fit. The contact surfaces of the tread plates exhibited rippling, as a result of cold working of the steel during operation. The flattening of the tread plates widened the plate cross section, inducing shear loading on the mounting bolts. The bolts required periodic re-torquing, or replacement due to the extreme shear loads.

II B - Operating Machinery -

The existing operating machinery on the bridge was installed as part of the Northeast Corridor Improvement Project in the early 1980's. Combined wear of the plates averaged 1/4 inch from their original thickness, which dropped the movable span in elevation. With the rack segments mounted on the fixed approach span towers, the change in elevation caused the main drive pinions to 'bottom out' in the rack. This resulted in high tooth contact stresses on the gear teeth, bending in the pinion shafts and excessive radial loads on the pinion shaft bearings. The operating machinery which normally carries machinery loads only was now carrying a portion of the span dead load.

The main pinion gears were translating off their shafts and were obviously misaligned as indicated by the abnormal wear patterns. AMTRAK personnel reported that this had occurred soon after installation. Operating machinery is not designed for high transverse loading, and therefore components began to fail. In addition to the pinions translating off their shafts, the lateral loading caused oscillations on the shaft mounted reducers. The result was a bending load applied to the torque arm which is designed for tension and compression loads only. The torque arm on the south side had failed at the threaded portion which resulted in an unsupported secondary reducer. AMTRAK personnel replaced the failed torque arm with steel plates used as links. Several mounting bolts for the main pinion bearing housing had failed and the housing was observed to move radially within the structural sleeve during operation.

II C - Determining Cause & Design Improvements -

In researching shop drawings for the existing bridge, it was discovered that the tread plates have been replaced about every twenty years due to wear. The reason for the frequent replacements of the tread plates is their unusually thin cross section given the high dead loads of such a large bridge. Currently AREA standards require the tread plates to be a minimum of 5 ½ inches thick for a bridge this large. The existing curved and flat plates are 2 and 2 1/4 inches thick respectively, which is less than half the required thickness.

The thin cross section of the plates was not enough to resist the flattening that occurred during operation. Increasing the thickness of the tread plates was not possible without major modifications to the segmental girder and/or elevation of the track girder. It was decided to maintain the same thickness, but to replace the tread plate with higher strength steel in order to reduce the rate of wear.

To improve the alignment of the rolling span during operation, the lugs were tapered. The lugs were also designed with a countersunk head on the underside of the flat plate in order to eliminate to possibilities of the lugs pulling out.

The worn tread plates were not the only cause for the abnormal loading to the operating machinery. It was apparent through field measurements that the rack segments were installed incorrectly during the 1985 replacement of the bridge machinery. Not only were the rack segments installed non-parallel to the translation of the pinion travel, but were also not parallel with respect to each other. This caused a cross mesh of the main pinion with the rack segments, which results in a transverse loads on the main pinion. The transverse loading forced the pinion off the shaft during span operation. At the time of inspection the pinion had walked of approximately 5 inches on the north side and 3 inches on the south side.

Considering the extent of damage to the existing components and the limited marine and rail closures that would be allowed, replacement of the damaged machinery was the only option. The only remedy for the poor alignment was to realign the rack segments and specify critical precision surveying of the structure for the installation of the operating machinery.

The cause of failure for the south reducer torque arm is also due to the transverse force which induced a bending load on the torque arm. The torque arm had no provisions for bending so the forces lead to a fatigue failure at the threaded portion.

The new torque arms were installed with spherical rod end bearings that will allow for any bending load caused by the pinion that may occur over time.

II D - Rail & Marine Traffic -

The main logistical problem in planning the rehabilitation was the fact that this bridge carries all the New York to Boston rail traffic, with no existing bypasses. Disruption of rail traffic would be extremely costly. Marine traffic is also heavy since the bridge is located at the mouth of the Connecticut River, and is the only marine route to Hartford. The construction would have to be scheduled after the pleasure craft season (between May and October), and not during the holiday schedule between Columbus day and New Years. This left only between January through April. The months of March and April were chosen in order to avoid harsh winter weather of January and February. Any closure would need to allow for periodic openings to allow for passage of fuel oil barges traveling to Hartford.

II E - Construction Scheduling -

The rehabilitation schedule ultimately chosen called for removal and replacement of the rear curved tread plates during a three day closure, four days of an operational bridge to allow for barge traffic, and a three day navigational closure for the rear flat tread plates. This would be referred to as phase Ia & Ib respectively.

After stage Ia and Ib were complete, the Contractor had a week and a half to prepare for the critical front tread plate replacement, which would be performed in a 39 hour rail closure with the bridge in the raised position. This 39 hour rail closure would be referred to as stage II, and was more critical since it required Amtrak to provide bus service between New Haven and New London train stations. Bus service would cost approximately $450,000 for 39 hours. Additional costs would be necessary should the installation run into any delays.

After stage II was complete, the Contractor would have another 1 ½ weeks to prepare for the 10 day navigational closure for the partial machinery installation, which included the rack segments, the main pinions and shafts, the secondary reducers and torque arms. Critical surveying was performed to measure the travel of the main pinions through out full travel. This was necessary to determine the placement of the rack segments.

III CONSTRUCTION DETAILS

III A - Phase I & II -

Since the existing tread plate mounting bolt locations varied +/-1/8 inch from the theoretical bolt centerline, each mounting bolt hole would need to be located in the field based on the location of the holes in the track and segmental girder flanges. This required the tread plates to be preliminarily aligned and clamped in place, each of the 800+ bolts were punch marked to locate their exact location, then the plate was removed and bolt holes drilled. Having to drill the 800+ bolt holes in the high strength steel plate, within the limited amount of time became a concern. The Contractor drilled sample pieces and timed the operation to be approximately two minutes from per bolt, using a titanium nitride coated drill bit and a magnetic based drill. This process proved to be adequate, causing no delays to the tight construction schedule.

Since the existing tread plates had been compressed to a thinner cross section, a step was created between the new and old plates, which was critical during bridge operation between stages I and II. Therefore the exiting plates were ramped to match the new tread plate elevation using shims between the girder flange and tread plate over a two foot transitional distance.

The most critical alignment was mating the curved and flat plates, and how to establish the travel existing of the tread plates. The existing lugs and pockets had been heavily distorted to the point that no datum line could be established. The Contractor developed a system to measure the bridge alignment during the operation. The travel was recorded by using an offset bracket attached to the track girder of the approach span and segmental girder of the movable span. The offset brackets served as a datum point for alignment of the new tread plates.

The removal of the north rear curved tread plate revealed , a ½ step in the segmental girder located at the rear portion of the new tread plate. This was created during the segmental girder repair performed in the early 1970's, when the radii of the north girder was corrected to match the south. The splice was stopped at that point, since any further would require modification of complicated structural connections that supported the overhead counterweight. It was an unforseen condition. It was decided to shim the gap between the girder and tread plate over approximately 2 feet transitional length. During an earlier rehabilitation in the 1950's, the span travel was limited to 59 degrees, since the bridge travel does not contact the step on the tread plate, this does not effect bridge operation.

III B - Phase III -

Once the tread plates were installed, an accurate survey of the pinion travel had to be measured. The survey had to be detailed enough to provide enough information to set the rack segments to the bridge travel both in elevation and plan. This was extremely critical since once the machinery was set there was little room for adjustment. Only the rack elevations could be modified with the addition of steel shim.

The new rack support angles location based on the survey deviated greatly from the existing location, since the existing rack segments were out of alignment at the north side. The difference was so much that the new angles would interfere with structural connections at several locations. The rack support angles had to be customly fit around the gusset plates at those interference points.

Since the main pinion elevation depends on the track girder elevation and the segmental girder radii, the pinion elevation deviated a total of 1/4 inch throughout the entire travel of the opening. It was decided to set the rack segments at the best fit with the pinion pitch line. The rack segments were set so the two high points were the deepest engagement with the pinion. The pinion teeth (with a circular pitch of greater than 4 inches) were large enough and strong enough to compensate for the varying pinion travel.

IV RESULTS

Phase I as expected served as a learning phase for the actual field details to determine the placement of the tread plates. The methods and time critical items learned were addressed and refined for the critical phase II construction.

Phase II was a long and busy 39 hours with much anticipation for the end result. Due to El Nino, 1998 was the mildest winter in recent history, but in late March during the scheduled weekend for rail closure, the only winter storm of the year struck. Snow, sleet and high winds were present for the majority of the 39 hour closure. The bridge offered little protection from the elements, so the Contractor rigged canvas to provide some sort of shelter. Phase II ended when the span lowered for the first time, without requiring the centering devices to align the span at the toe. The track rail elevations at the heel were adjusted for the new tread plate thickness. There was no delay to the train schedule.

Phase III incurred few minor field adjustments, with the operating machinery installed and aligned correctly. The pinion/ rack tooth alignment was better than expected throughout the travel of the bridge, thanks to the precision survey performed by the millwrights.

Throughout the project the Contractor as well as Amtrak construction personnel exhibited excellent decision making and coordination that resulted in a successful emergency repair.