Paper No. 13

Performance/Construction/Maintenance

Spuyten Duyvil Emergency Response To Navigation Strikes

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TENTH BIENNIAL SYMPOSIUM

OCTOBER 25 - 28, 2004
The Omni Orlando Resort at ChampionsGate

INTRODUCTION

Twice within eleven months, Amtrak's Spuyten Duyvil Railroad Swing Bridge, located at the northernmost point of Manhattan, New York City, was struck and damaged by errant navigation. Each time, a team of Amtrak engineering personnel, Hardesty & Hanover design engineers, and American Bridge construction workers, responded rapidly to provide the design and construction services necessary to restore the railroad to service and the bridge to full operability for navigation.

This paper presents special issues that were addressed during these emergencies including structural, electrical, and mechanical work; temporary and permanent repairs; and the communication and coordination efforts required for a fast-moving project.

BACKGROUND

Figure 1. Spuyten Duyvil Railroad Swing Bridge

Amtrak's Spuyten Duyvil Railroad Bridge is located on Amtrak's Empire Line at milepost 10.20. Amtrak provides long distance, passenger rail service between New York City and points in upstate New York, such as Poughkeepsie, Albany, and Niagara Falls, as well as other destinations north of the city, e.g., Detroit, Michigan, and Montreal, Canada, that use this line crossing over the Spuyten Duyvil Bridge. Approximately 30 trains per day traverse the bridge. The bridge crosses over the Spuyten Duyvil waterway at the point where the waterway flows into the Hudson River. The waterway is navigable, and the bridge includes a swing-type draw span to permit the passage of vessels.

Figure 2.. Spuyten Duyvil at Track Level

Originally constructed in 1899 by the King Bridge Company for the New York Central Railroad, this bridge on the west side line served for many years as a key link for freight delivery by rail to the west side of New York City's main borough of Manhattan. Freight rail service to Manhattan dwindled in the years after World War II, but continued through the takeover of the line by Conrail in the 1970's, and into the 1980's. In the 1980's, Conrail discontinued all service on the line. Amtrak acquired rights to the line, and initiated a program to start passenger service on the line, switching existing services based from New York's Grand Central Terminal at 42nd Street in midtown on the east side, to Amtrak's Pennsylvania Station at 34th Street on the west side of Manhattan. The program included providing a new tunnel connection between the west side line and Pennsylvania Station; improving the tracks, signals, and security along the line through Manhattan; and reconstructing the Spuyten Duyvil Bridge. As the program was completed in 1991, Amtrak was able to save costs through the elimination of service facilities and personnel at Grand Central, and to encourage increased ridership by enabling passengers to make direct connections between trains on the Northeast Corridor and Empire Line.

The Spuyten Duyvil Bridge was completely reconstructed in 1991 by Amtrak in agreement with the State of New York. For the reconstruction project, Hardesty & Hanover (H&H) provided engineering design services and American Bridge provided construction under contract.

The bridge crosses a navigable waterway. The original Dutch settlers of New York named the waterway "Spuyten Duyvil," which means "Spitting Devil." Whatever the original intent of the name, it aptly describes the swift and turbulent character of the water currents that pass by the bridge. The direction and speed of the currents vary with tidal flow. The currents from Spuyten Duyvil mix with the flows of the Hudson River immediately west of the bridge, producing varying degrees of turbulence, depending on tide and water level conditions.

SPUYTEN DUYVIL BRIDGE DESCRIPTION

The bridge consists of four spans. Originally constructed for two tracks, the bridge currently carries one track along the east side.

The main span is a 286-foot long through-truss, drawspan. The drawspan is most correctly classified as a hybrid rim- and center-bearing swing span, supported on a heavily structured turntable. The bridge's center span design loads are distributed with 75% being supported by 64 roller wheels along a circular track mounted on a circular pier (the rim), and the other 25% supported in a center spherical bearing dish. The center support for the bridge is best considered as a four- layer concept. The uppermost layer, the through truss bridge itself, is framed at its center via a square arrangement of heavy, cross and longitudinal girders. These girders rest on the second layer, a symmetrical frame of eight distribution

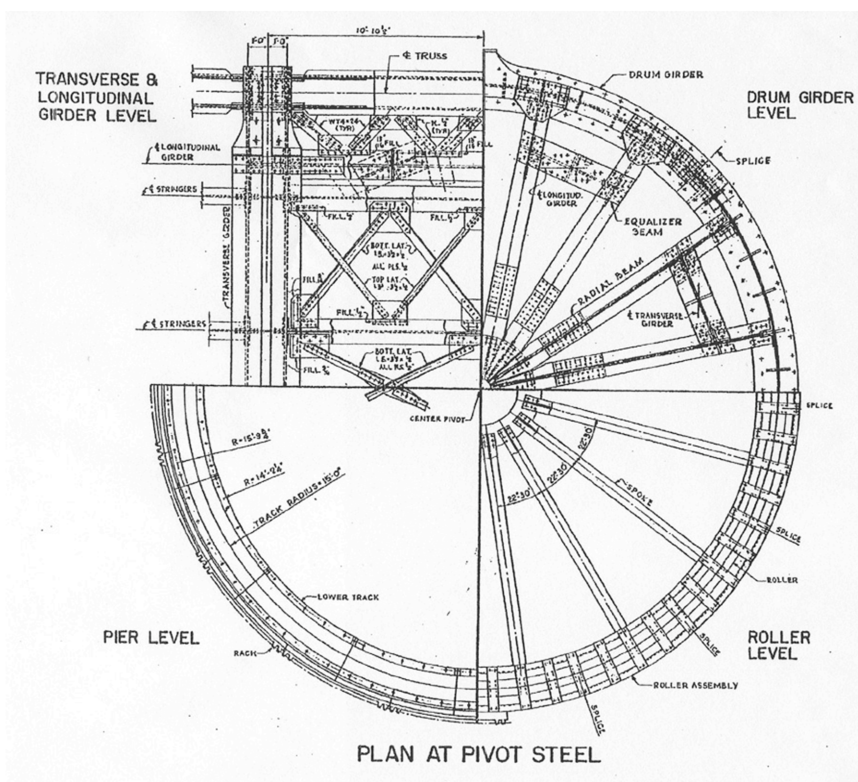

Figure 3. Spuyten Duyvil Turntable Plan

beams connected into 16 radial beams, which are in turn framed into a center hub and a circular ring beam. The third layer is the set of 64 roller wheels connected by spokes to a center bearing disk. The fourth, and lowest layer, is the base circular track and bottom dish of the center bearing that are mounted on the circular pier.

Three identical, 106-foot long through truss spans form the approach spans—one to the north, the Bronx side, and two to the south, the Manhattan side.

A timber fender system, consisting of timber pile dolphins and pile-supported heavy timber framework, marks the two channels that pass by the open draw of the bridge. These fenders provide some protection from navigation strikes along the center pier, the two rest piers, and the drawspan, when in the open position.

Figure 4. Spuyten Duyvil Drawspan Opens for Navigation above Fender Systrem.

Operation of the bridge from the closed (railroad active) position, is dependent upon the Bridge Operator, located in a house above the center of the main span, radioing the Train Dispatcher to request "control" of the railroad. Subsequent to gaining control, the Operator initiates the bridge operation by pressing a button on the control panel that results in the withdrawal of four steel wedges, one at each corner of the main span of the bridge, causing the ends of the main span to droop and hang free of the rest piers upon which the bridge is normally supported. The wedge withdrawal operation is mechanically interlocked with lift mechanisms for the running rails, such that while the span hangs free, the rails are lifted clear of the approach span to allow the bridge to swing past the approach structure.

The Operator then presses another button to cause bridge rotation in the clockwise direction. By the power of electric motors driving through a series of shafts and gear reducers, the bridge is driven by two large pinions that engage a circular rack mounted along the perimeter of the center circular pier. The bridge opens nearly 90 degrees creating two, 100-foot wide channels available for navigational use.

The bridge is opened for navigation over 1000 times per year. Openings occur more frequently during the summer months when the Circle Line tourist sightseeing boats and recreational craft require use of the channel.

Figure 5. Spuyten Duyvil Bridge Open to Allow Passage of Circle Line

FIRST INCIDENT, MARCH 2002

On Saturday, March 3, 2002, the Amtrak Spuyten Duyvil Bridge was struck by a barge loaded with old subway cars destined for an artificial reef site. After hours of railroad delays, Amtrak forces were able to close the bridge. Amtrak maintenance forces then noticed that not only was there obvious damage to the timber fender system and control house stairway, but the rim-bearing swing span had been pushed over 1.5 inches, thereby causing distress within the turntable structure and the electrical operating systems.

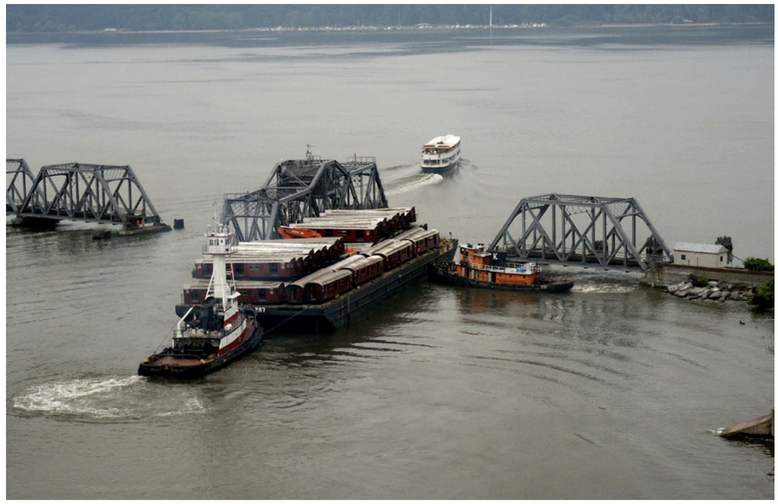

Figure 6. Barge with Subway Cars Passing through the Open Spuyten Duyvil Bridge

Amtrak called Designer, Hardesty & Hanover, and Contractors, American Bridge and Cianbro, to the site on the following Monday to provide their evaluation and possible restoration plans. The team decided to lift-jack the 750-ton swing span in the middle, and to push-jack the span back, thus causing a reaction against the approach truss spans. Proper blocking was provided to brace the spans back to the abutments.

H&H provided the load analysis and detailed jacking procedure; Cianbro provided sliding plates from their stock; American Bridge obtained and set-up the jacks and supports; and Amtrak worked on blocking the approach spans and arranging for safety training.

Starting late at night on Friday, March 8, 2002, the team jacked (in stages) the bridge back into proper position. We then removed the jacking to permit the span to swing. While performing test operations, the bridge partly recoiled toward the displaced position. The following Monday night, we repeated the "pushing and lifting," working the bridge to the point of successfully restoring the swing span to its proper, permanent position.

Figure 7. Emergency work through the night at Spuyten Duyvil.

Damage caused to the timber fender system during the bridge strike was surveyed and repair plans were prepared and offered in a contract. In these repair plans, the replacement fender system was upgraded to include greater protective and energy absorption characteristics at the center pier. Prior to scheduling these repairs, a second, navigational strike occurred.

SECOND INCIDENT, FEBRUARY 2003

Less than one year after Hardesty & Hanover was requested to provide emergency services to Amtrak after the Spuyten Duyvil Bridge had been struck and damaged by a barge, the Designer firm again received an emergency call informing us of another navigational hit. Whereas the previous year's navigational hit merely dislocated the bridge from its center bearing, additionally, the latest strike caused severe damage to the structure, the mechanical drive system, and the electrical power supply.

Figure 8. Crushed Steel Truss Duyvil Bridge

Early Friday morning, February 7th, 2003, Alex Ostrovsky of Amtrak phoned Craig Rolwood (H&H) at home, and informed him that the open swing span of Spuyten Duyvil had been struck by a barge in the middle of the night, sending the span swinging in the wrong direction. It was conveyed that the damage comprised a deeply damaged fender system; crushed structural steel truss members at the point of impact; torn, flexible power feed cables ripped from their junction box connections; and sheared pinion shaft bearing block bolts cut from their base connections. By early morning, the span had been pulled shut using the tug that had caused the damage; however, train service over the span was suspended due to the damaged truss.

Cell phones became invaluable tools over the next few days, used to mobilize and manage the emergency repair schedule. Craig Rolwood drove through a heavy snowstorm to the H&H Trenton office and was able to reach Andy Herrmann (H&H) on his cell phone as he was preparing to board his inbound commuter train to NYC. Andy arrived at Spuyten Duyvil, via Metro North, by 9:00 a.m. and was able to mobilize structural, mechanical and electrical inspectors from New York, all by cell phone. In the meantime, Craig continued on his journey through the snowstorm to Upper Manhattan.

When Craig arrived in Upper Manhattan at 10:30 a.m., Amtrak systems and division engineering people were on site; H&H was fully mobilized; and Contractor, American Bridge, had people on site, sent over from their nearby construction project. Together, we surveyed the damage and determined that the first priority was to restore train service as soon as possible. We began setting up lines of communication between designer, contractor, fabricator, and supplier to develop a workable design of temporary repairs using available materials. This challenge, while being complex under the normal "short notice" conditions, was additionally complicated due to the fact that we faced it on a weekend.

Over Saturday, Sunday, and into Monday, H&H worked closely with American Bridge and their fabricator to produce a temporary repair based upon available, high strength threaded rods, simple plate weldments, and field bolted connections. Designs were prepared "just-in-time," Friday evening, Saturday, and Sunday morning. The final bolt count and pattern design for one temporary piece was completed at 2:00 a.m. on Monday inside the control room of the Spuyten Duyvil Bridge. H&H supported the repair construction with field presence over the weekend. Temporary repairs were completed by Monday night.

Figure 9. Temporary Steel Supports

Figure 10. Temporary Steel Supports

Figure 11. Mechanical Repairs of Pinion Shaft Bearings

Amtrak then opted to jack the bridge back into proper alignment on Tuesday morning while crews were mobilized using the system we had developed nearly a year ago. Train service was restored by Tuesday evening.

While structural repairs were underway, the H&H electrical department assisted Amtrak in locating a source for a replacement, flexible cable. H&H's mechanical department provided assistance to Amtrak with the inspection work, the measurements taken during the jacking operation, and the reuse of the less damaged pinion, incorporating it to render the bridge mechanically operational.

Permanent structural repairs were then designed. Intensive coordination was required between Amtrak; Contractor, American Bridge; and Designer, Hardesty & Hanover to assure the constructibility of the design within tight, railroad operations windows. At this point mechanical replacement parts were ordered for installation.

Work to perform the permanent, structural steel repairs was coordinated with the repair work on the fender system, damaged from the first bridge strike incident in 2002, and the mechanical installation. The work occurred, first during the daytime, to complete that which could be accomplished during active rail operations, then secondly, at night—completing work that would foul the track.

In May 2003, once repairs were completed, H&H, along with Amtrak and American Bridge, repositioned and again, performed jacking of the bridge to restore it nearly to its correct, centered position for operations. Although the process for jacking of the bridge was essentially the same as that used the year before, this time the bridge needed to be jacked back in the opposite direction.

Hardesty & Hanover was requested to prepare contract drawings for repair of the damaged fender system from the second bridge strike incident based on information Amtrak had discovered from a diving inspection done after the damage occurred. H&H performed the repair design and details by the end of the summer, 2003.

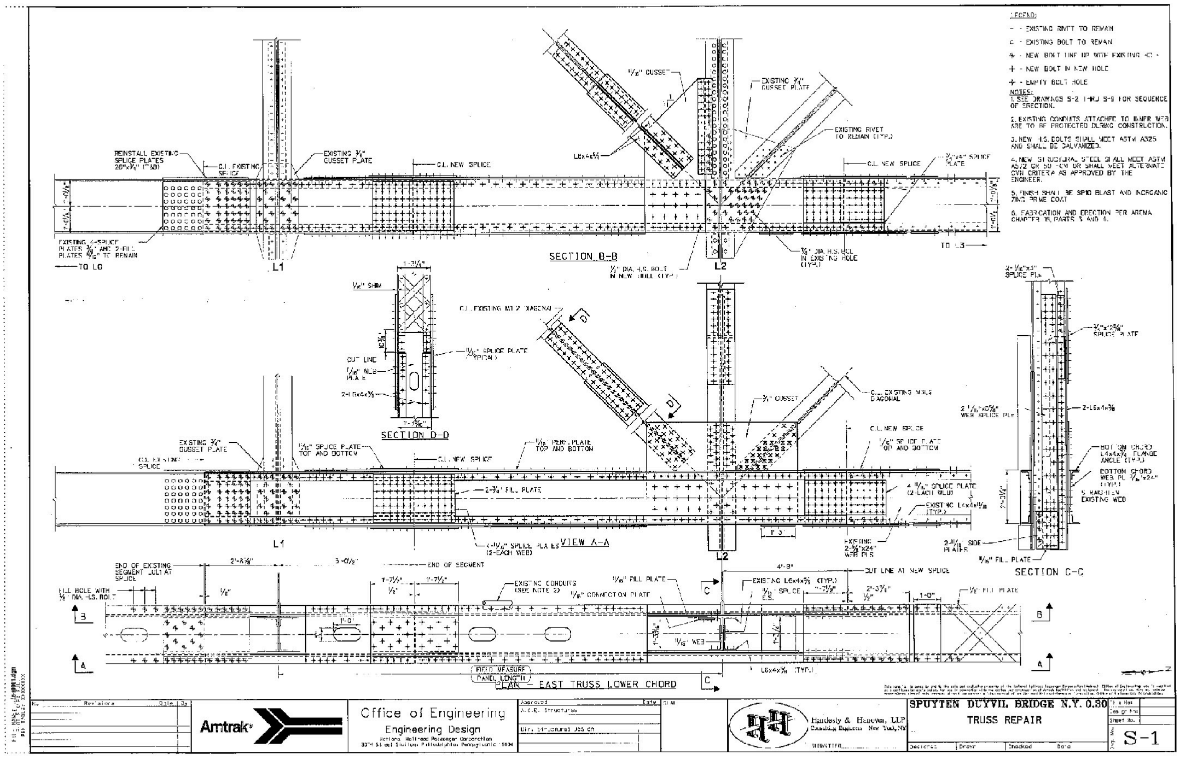

Figure 12. Permanent Steel Repairs

ICE DAMAGE, WINTER 2004

Before Amtrak could contract for the work to repair the fender system, extreme weather conditions during the winter of 2003/2004 resulted in further, severe damage to the west end of the fender system, where it extends out into the Hudson River.

Figure 13. Heavy Ice Conditions, January 2004

Unusually cold temperatures for extended periods of time during the month of January produced heavy ice conditions on the Hudson River. Tidal variations and river flow along the shore created heavy slabs of floating ice. Some of these ice flows became lodged under the fender sheathing and among the timber pilings along the northwest corner of the fender system. The existing damage was compounded by deteriorated pile conditions, and resulted in large portions of the fender system breaking away due to the severe forces of ice flows against the timber fendering.

CONCLUSIONS

We found a number of noteworthy elements that contributed to the successful execution of the emergency work for both occurrences, and done so under conditions sometimes stressful.

- **Communication.** Tools of the 21st century were used to maintain continuous and near instantaneous communications, accelerating the flow of the work and resolution of problems. These tools included cell phones, e-mail, faxes, and electronic scanning of sketches. Still, and most importantly, the one common element to all these tools was the user, the human individual.

- **Attitude.** Early in the process, ideas and information flowed in increasing quantities. Necessary attitudes for using the information to accomplish our goals included:

    - Flexibility. The "normal" design process takes time, and involves multiple iterations and work toward an ideal solution. For a time-critical emergency project, the designer needs to be prepared to change direction as new information arises, yet continue to maintain forward momentum to bring the process to a conclusion. For example, one design element designed Saturday afternoon and evening and under fabrication during the early hours on Sunday, was significantly modified later that Sunday morning to permit much simpler fabrication and also afford an ultimate savings in time and money.

    - Perseverance. The work can be tiring. During the critical first few days, some of the designers and construction managers stayed awake—more than 24 hours at a stretch.

    - Teamwork. All parties involved worked together in a spirit of cooperation with recognition of each other's strengths, resources, and abilities, without which there would be no hope for success. Egos were left home.

- **Experience.** A thorough knowledge of steel design, railroad operations, materials procurement, steel fabrication, heavy construction methods, CAD production, and movable bridge electrical/mechanical design was needed to accomplish the work. While no one individual has the depth of experience and contacts in all these areas, the team, working together, was able to pool experience to quickly accomplish the required work.

After receiving hard and damaging blows from errant navigation, the Spuyten Duyvil Bridge has been restored to serviceability for both rail and navigation operations. However, during operations over the past year (since the latest bridge strike), Amtrak and Hardesty & Hanover have noted that the main span does not seem to operate quite the same as before the strikes. Two specific things have been noted:

- One—during certain mornings in the summer, the southeast corner of the main span that had been struck and repaired, droops enough during some opening operations to just scrape across the top of the opposite wedge base ears during opening. Amtrak mitigated this condition by slightly grinding the wedge base ears to assure clearances. One plausible theory for this is that the temporary and permanent repairs performed have left a slight sag camber in the southeast corner.

- Secondly—the electrical power draw during openings is not as smooth as it was previous to the strikes. While there have been no operational difficulties, we theorize that the span center bearing and 64 rim wheels do not align as perfectly as they did prior to the strikes and the subsequent re-centering jacking procedures that were performed.

One person has likened the current bridge condition to an automobile that has been in a passenger side collision and subsequently repaired—the car is more than adequate to get you where you want to go, but the side door just does not fit the frame with the same clean looking lines as before.