Ownership/Public Use/Management

Replacement of the Route 7 Bridge over the Passaic River

Belleville and Kearny Townships and North Arlington Borough Essex, Bergen and Hudson Counties, NJ

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ABSTRACT

The Route 7 Bridge over the Passaic River, owned by the New Jersey Department of Transportation, was designed by Hardesty & Hanover, LLP Consulting Engineers. M.J. Paquet, Inc. constructed the bridge.

The new tower driven vertical lift bridge replaces an 85-year-old, single-leaf Strauss heel trunnion bascule bridge that was determined to be in critical condition due to low live load capacity, minimal remaining fatigue life, and failure to meet AASHTO seismic criteria. The new Route 7 Lift Bridge comprises two, 81-ft approach spans; two, 16-ft 6in. tower spans; and a 125-ft lift span.

The project goals—to maximize the design life and minimize the life cycle costs of this structure—were paramount and directed many design decisions that were made during the project. To that end, NJDOT and the designer decided to use LRFD, metalizing, and silica fume concrete in the deck gratings—all used for the first time in a New Jersey movable bridge design—and to assess their benefits over the design life of the bridge. These and other efforts are reflected in a new lift bridge that is visually appealing, technically proficient, and fiscally responsible.

Keywords: Vertical Lift Bridge, Lift Span, Route 7 Bridge, LRFD, Metalizing, Silica Fume Concrete, Integral Abutments, Synchro-tie Motors, Programmable Logic Control Desk, Retractable Barrier Gates

Introduction

This project includes the on-line replacement of an existing 4-lane, multi-span, low-level bascule bridge. The existing bridge measured 330ft long and 59ft wide. The new tower driven vertical lift bridge, which was opened to traffic on August 24, 2002, is 320ft long and 69ft wide. The bridge, owned by the New Jersey Department of Transportation, was designed by Hardesty & Hanover, LLP Consulting Engineers. M.J. Paquet, Inc. constructed the bridge.

The former Route 7 Bridge over the Passaic River was a historic, 116-ft, single leaf Strauss heel trunnion bascule span built in 1915 (see fig. 1). The total length of the old bridge was 330ft, including the bascule and the approach spans. The bridge carried four lanes of local traffic on a 39-ft wide deck, plus two sidewalks. Route 7 runs east-west, connecting the town of Belleville on the west side of the river with the Town of Kearny and Borough of North Arlington on the east side.

Fig. 1. Former Rte 7 Bridge (Belleville Reformed Church in Background)

The new Route 7 Lift Bridge is 320ft long and includes two, 81-ft approach spans; two, 16-ft 6in. tower spans; and a 125-ft lift span. It carries two, 12-ft lanes; two, 15-ft lanes; and two, 6-ft sidewalks (see fig. 2). The east approach span widens toward the abutment to accommodate a left turn lane at the east end of the bridge. The towers and the approach span, lift span, and tower span superstructure are A709, Grade 345 structural steel. All substructures are reinforced concrete.

Fig. 2. Present Rte 7 Bridge

The project goals to maximize the design life and minimize the life cycle costs of this structure were considered paramount and directed many design decisions that were made during the project. To that end, the design utilizes LRFD, metalizing, and silica fume concrete in the deck gratings—all for the first time on a New Jersey movable bridge—and the owner will assess the benefits of these design decisions over the design life of the bridge. These and other efforts are reflected in a new lift bridge that is visually appealing, technically proficient, and fiscally responsible.

Project Rationale and Owner Needs

In use since 1915, the Route 7 Bascule Bridge was in poor condition by the time this project began in the late 1980s and continued to further deteriorate in the years leading up to construction. Many of the steel members were severely corroded, the lanes were less than 10ft wide, and the operator's house was in poor condition. The bridge was closed often for repairs. NJDOT determined that the entire bridge should be replaced since its useful life was limited and widening the bridge was not feasible.

NJDOT issued the following mandates for the project:

1. Minimize wetland impacts
2. Minimize ROW acquisitions
3. Minimize environmental impacts
4. Minimize project impact on its termination points on both sides of the Passaic River
5. Study both fixed and movable alternatives, conforming to AASHTO and NJDOT standards
6. Minimize life cycle costs of the new structure
7. Minimize travel delays associated with required detour

In addition to the above mandates, several project constraints limited the possible alignments and profiles that could be chosen for a new bridge. An elevated highway, Route 21, runs parallel to the river on the west side, which required the design of either a long high-level fixed bridge in order to meet clearance requirements, or a low-level bridge alignment to fall within a narrow corridor in order to avoid the horizontal and vertical constraints imposed by the elevated highway and its piers. Also, the Belleville Reformed Church—established in 1697 and designated a National Historic Site—and its surrounding residential neighborhood on the west side of the river presented an historic resource that would be visually impacted and physically divided by the addition of a high-level bridge. The church's location limited any substantial shift to the south for the low-level alignments.

The hydraulics of the Passaic River presented another project constraint. The analysis of the 100 year storm event indicated that movable bridge piers must be designed with rounded faces and specified a maximum width in the waterway of 85 feet in order to meet stream encroachment permit requirements. Also, the minimum superstructure elevation had to be above the 100 year storm elevation.

The location of Conrail tracks in Belleville required designs to place all alignments to touch down east of the tracks, thus limiting the high-level alignment design speed to 30 mph.

Vertical and horizontal clearance requirements were determined by the US Coast Guard: minimum vertical clearance in the closed position, 8ft; vertical clearance in the open position, 50ft; and horizontal channel clearance, 100ft.

Historic Bridge

NJDOT was attempting to replace an existing bridge that was eligible for the National Register of Historic Places. This required close coordination with the State Historic Preservation Office including the completion of a Historic Bridge Alternatives Analysis and mitigation through commemorative plaques and historical color schemes in order to gain SHPO's approval for the replacement of this historical bridge (see figures 3 and 4).

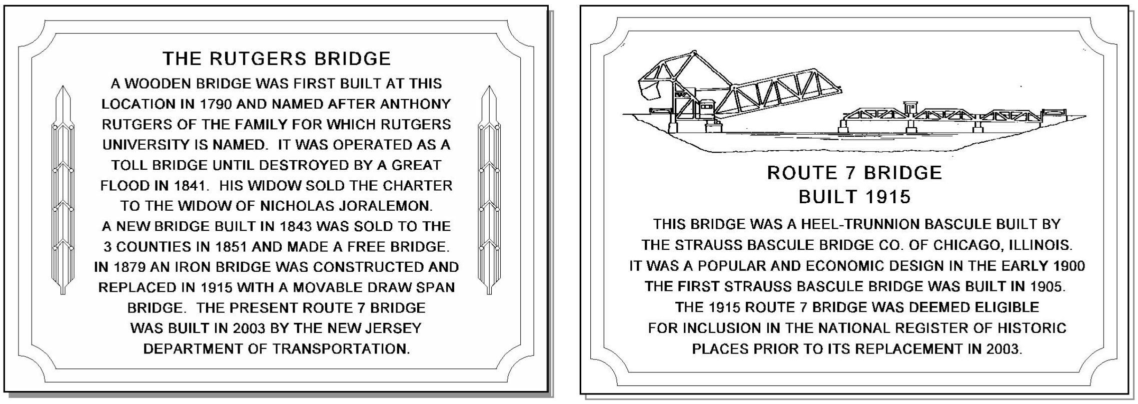

Fig. 3 and Fig. 4. Commemorative Plaques

A wooden bridge was first built at the present Route 7 bridge location in 1790 and named after Anthony Rutgers of the family for which Rutgers University is named. It was operated as a toll bridge until destroyed by a great flood in 1841. His widow sold the charter to the widow of Nicholas Joralemon. A new bridge was built in 1843, and sold to the three counties—Essex, Bergen and Hudson—in 1851 and made a free bridge. In 1879, an iron bridge was constructed and then replaced in 1915 with a movable draw span bridge—a heel-trunnion bascule built by the Strauss Bascule Bridge Company of Chicago, Illinois. It was a popular and economic design in the early 1900s. The 1915 Route 7 Bridge was deemed eligible for inclusion in the National Register of Historic Places. Plaques, installed on the approach span parapets, describe the history of the bridges preceding the new Route 7 Vertical Lift Bridge.

Detour

H&H worked closely with local officials, business owners, and police departments to develop a workable traffic detour that would minimize unavoidable travel delays and impacts to surrounding businesses.

Subsequent to the bridge shut down, there were two immediate crossings for alternate routes to the north of the Route 7 Bridge—the Park Avenue-Kingsland Avenue Crossing, and to the south, the Clay Street-Central Avenue Crossing. Adequate signing was provided along River Road in North Arlington, the primary detour route. During the initial period following closure, police traffic directors were deployed to assist in expediting traffic flow through the intersections which were expected to become congested, e.g., Kingsland Ave/River Rd. Advanced warning signs were positioned to alert heavy trucks and tractor-trailers to use alternate crossings via Kearny Ave/Ridge Rd, thereby minimizing impacts along the more residential areas and a park along Passaic Avenue. Detour signs were installed along Broadway, Washington Avenue, McCarter Highway (Rte 21), Kearny Ave/Ridge Rd, and Schuyler Ave. Variable

Message Signs (VMS) were placed along Routes 3 and 7 to warn motorists of the Route 7 Bridge closure and to advise the motorists to plan alternate routes.

The Route 7 Lift Bridge

Of the three alternatives studied—the high-level fixed bridge, the lift bridge, and the bascule bridge—the lift bridge was determined to be the most economical alternative. Furthermore, the lift bridge alternative required the least ROW acquisition, did not affect parkland or wetlands, and resulted in only minor visual impact to the surrounding neighborhoods. The vertical lift bridge alternative required the design of complex contract plans necessitating close coordination between mechanical, electrical, and structural elements. Hardesty & Hanover was able to complete these complex plans on schedule.

The bridge superstructure consists of two, 81-ft approach spans; two, 13-ft tower spans; and a 124-ft lift span.

The lift span superstructure is 72ft-7in. wide and consists of a 54-ft roadway and two, 6-ft sidewalks inboard of two, through steel box girders. The box girders are 7ft-6in. deep and 3ft-6in. wide. The roadway carries two, 12-ft center lanes and two, 15-ft outside lanes. Rolled section stringers at 6-ft-9in., centers frame into steel floorbeams at 25-ft spacing. The top flanges of the floorbeams follow the cross slope of the roadway (see fig. 5).

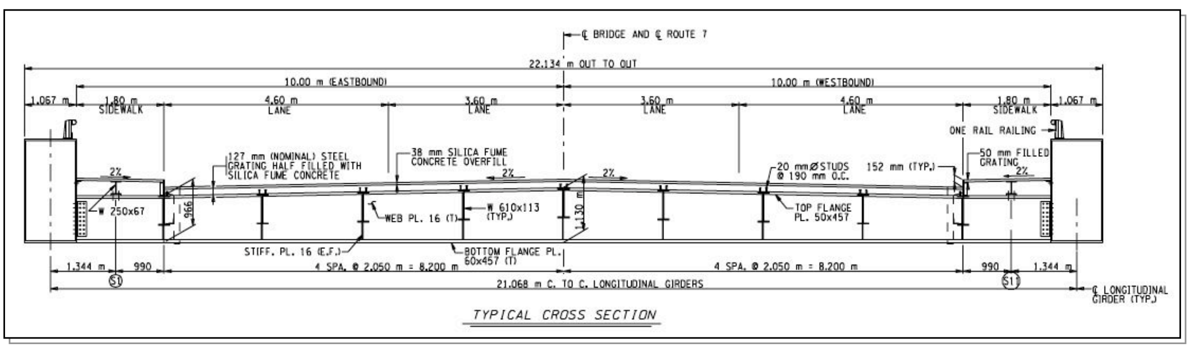

Fig. 5. Typical Cross Section at Lift Span

The deck consists of 5-inch, galvanized steel grating half filled with silica fume concrete with a 1.5 in. overfill to provide a concrete riding surface. The sidewalks are 2 inch galvanized steel grating with silica fume concrete fill. The through girder superstructure with floorbeams and stringers was chosen for the lift span because a shallow superstructure was required to accommodate the roadway profile, vertical underclearance, and river hydraulics.

The lifting girders are shallow, steel box girders, 4ft-1in. deep (max.) and 2ft-2in. wide. The top flange of each girder follows the cross slope of the bridge. The towers are also constructed of steel box members. Machinery is housed within the top of each tower, and the control house is located in the west tower above the roadway (see fig. 6).

Fig. 6. Control House

Each tower comprises eight (8) tower columns, four on either side of the roadway. These tower columns, each approximately 100ft tall, support machinery houses that contain the majority of the mechanical components. The lifting weight of the bridge is approximately 1.2 million pounds.

Fig. 7. Sheave Installation

The Route 7 lift span is counterbalanced by wire ropes that pass over counterweight sheaves and connect to two counterweights. There are two (2) sheaves in each tower that carry and direct the loads from the span to the counterweight through the wire ropes. There are eight (8), 2_-in. diameter wire ropes per corner of the span/sheave. The two groups at each end of the lift span connect to a single counterweight in each tower. Each sheave has a ring gear attached at the rim that is driven by a pinion (see fig 7). The two pinions in each tower are driven by a single gear reducer through cross shafts.

The tower and approach spans have reinforced concrete sidewalks and decks supported by steel stringers. The approach span stringers are built-up members; the tower span stringers are rolled sections. The approach and tower span superstructure is 67ft-7in. wide, with the east approach span widening to 70ft-9in. at the east abutment.

The substructure consists of two reinforced concrete integral abutments on steel H piles and two reinforced concrete tower piers on 4-ft diameter drilled shafts. The drilled shafts have a design capacity of 450 tons and are socketed 7ft into rock. The ends of the tower piers are rounded to reduce stream profile changes.

Innovative Elements of the Design

The Route 7 Lift Bridge presented the designers and owners with several challenges and opportunities:

1. This bridge is NJDOT's first movable bridge designed with the **AASHTO LRFD specification**. The lift span was designed using LRFD. The approach spans were designed using the allowable stress method per NJDOT's bridge manual requirements.

2. The design specified that all of the structural steel, including lift span, towers, and approach spans, be **metalized** and then painted with a urethane finish coat. The interiors of the box members were metalized only. This is the largest application of metalizing to date on an NJDOT

bridge, and the first application on a movable bridge in New Jersey. The metalizing serves to improve the corrosion resistance of the steel and to decrease life cycle costs. The Passaic River is a tidal river and is therefore, brackish. Moreover, New Jersey uses salt on its roadways during the winter months. Studies indicate that metalizing of steel structures will endure 4-8 times longer than a conventional paint system would; the initial metalizing of the Rte 7 span should last for the bridge's design life. A zinc alloy coating 200-250mm thick was used on this project. Although it was applied by a coating subcontractor, the work was done in the steel fabricator's shop. The total cost of structural steel, fabricated and erected, for this project was $9.6 million. It is estimated that using a metalized coating vs. paint added approximately $800,000—8% of the structural steel bid price—to this project. However, it is also estimated that during its design life the bridge would need to be repainted four times, at an approximate total present cost of $1.6 million.

3. **Silica fume concrete** was used on the sidewalk and deck gratings as an additional anti-corrosion measure. Again, this was NJDOT's first use of this material on a movable bridge. The silica fume concrete reduces the propagation of chlorides through the concrete by providing fewer voids through which water can travel. It is expected to double the life of the deck, compared to conventional concrete. The increase in cost incurred by the use of silica fume is estimated to be less than 10%. In addition, a calcium nitrite-based corrosion inhibitor admixture was used in the remaining concrete, including all substructures and the approach and tower span decks.

4. **Steel details were simplified** and refined for ease of fabrication and maintenance. The towers were designed as rigid frames to eliminate tower bracing and to contribute to the appearance of the structure. Furthermore, the box member welding details and specified procedures simplified fabrication while meeting AASHTO fracture critical weld requirements. The box members were detailed so that tension flange to web groove welds were made first, forming a U-section and allowing the tension flange welds to be back-gouged. The compression flange welds that close the box were made using back-up bars. Thus, all welds were made from outside the box.

5. **Integral abutments** were used to reduce the maintenance issues associated with deck joints.

6. **Tower pier widths were minimized** to meet stream encroachment limits. To meet seismic requirements, the tower piers were designed with hollow sections to reduce their mass. The piers have rounded ends to minimize stream profile changes in this flood-prone location (see fig. 8).

Fig. 8. Tower Pier with Rounded Ends

7. To make the unavoidable **visual impact of the towers an asset** rather than a liability, aesthetic consideration was emphasized in the selection of colors and surface treatments of the superstructure, operator's house, and towers. The design incorporated a palette of gray and ivory with red accents for the towers and house. The red accents were designed to help the towers blend in with the historic Belleville Reformed Church. The lack of tower bracing also contributes to the clean lines and uncluttered appearance of the bridge.

8. The Route 7 Bridge has a diesel engine/generator that is large enough to lift the span in the event of utility power outage. The engine/generator is located on the northwest side of the bridge in its own dedicated room.

   Electrical motors are used to lift the bridge span. Motors are located in each machinery room. Special motors, known as **Synchro-tie motors**, are selected to limit skew. Skew is the tilting of a span on one side due to factors such as wind, snow, etc.

9. A state-of-the-art **Programmable Logic Control Desk** was designed for the Operator to start/stop/monitor the lifting operation (see fig. 9). The control scheme is completely automatic, although it can be run manually, if necessary. NJDOT's Movable Bridge Engineering Group will be able to monitor the lift span operation in **real time graphics** from their offices located in Freehold, NJ, about 60 miles from the bridge site. This is the first time such computer graphics have been utilized on any bridge in New Jersey.

Fig. 9. Programmable Logic Control Desk

10. A camera has been installed on the West Machinery Room Tower to view Rte 21 traffic (see fig. 10). To provide **real time traffic reports** to the traveling public, this traffic view will be shown on "Metro Traffic and Weather"—a cable channel with the motto "Know before you go." A total of six (6) such cameras located at various points on the bridge will transmit views to the NJDOT's North Traffic Operations Facility located in Elmwood Park.

Fig. 10. View of Route 21

11. As an improvement to driver safety and NJDOT maintenance responsibilities, **Retractable Barrier Gates** have been installed for the first time on a movable bridge in New Jersey. In the event a vehicle attempts to cross the bridge when the span is lifted, these gates are capable of stopping, within 30 feet, a vehicle traveling up to 50mph. The gates are designed in such a way that the driver will be unharmed, and the nets can be retracted in a minimal time without the need for a maintenance crew on site.

Completion of Project

The Route 7 Lift Bridge opened to traffic on August 24, 2002, slightly later than the scheduled opening of July 14, 2002. The delayed opening was primarily due to delays in steel fabrication. The construction costs were within 5% of the budgeted costs. The new bridge and the intersection improvements at both ends of the bridge provide users of Route 7, a state-of-the-art crossing that meets all current design standards, improves safety, and minimizes travel delays. Moreover, the owner and designer's willingness to use new materials and techniques, and to examine not just the initial cost of the structure but also its life cycle costs, resulted in a bridge that should encounter few significant maintenance problems during its design life.