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Rehabilitation of the Route 250 Lift Bridge
Fairport, New York

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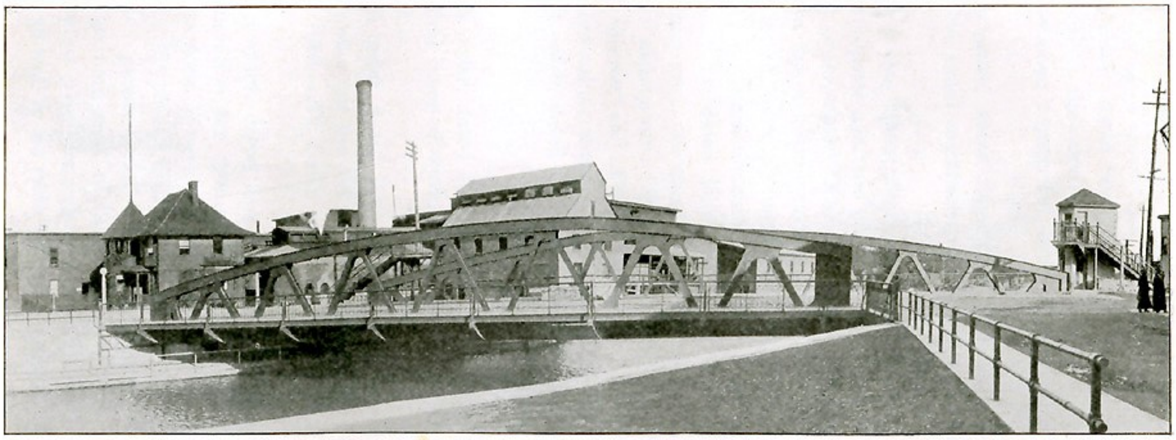
Introduction

This paper presents the rehabilitation of the Route 250 Lift Bridge over the Erie Canal in Fairport, New York. This circa 1914 “tower-less” vertical lift bridge is one of sixteen lift bridges which span the canal between Fairport and Lockport in western New York. However, Fairport Lift Bridge is unique in both geometry and operating system when compared to the other canal lift bridges. In addition, due to its central location, the bridge is a focal point for the community and was named a village landmark in 2009. Therefore, this project required both functional and aesthetic considerations to satisfy all project shareholders. The project was a 2022 Bridge of the Year award winner of the Western NY Association for Bridge Construction and Design.

This paper will discuss key features of the design as well as the adoption of new technologies to modernize the bridge and engineering solutions to address pre-existing conditions while retaining the historic character.

History

Fairport Lift Bridge was built under Contract 63, awarded to H.S. Kerbaugh Inc. of Philadelphia, Pennsylvania, on June 13, 1910. This contract covered 12.22 miles of the canal from Wayne County to Kings Bend.



BARGE CANAL, CONTRACT NO. 63
Fairport lift-bridge, a skew bridge. General view of structure and vicinity.

Figure 1 – Fairport Lift Bridge from Annual Report of the State Engineer and Surveyor of the State of New York for fiscal year ended September 30, 1915 (Albany: J.B. Lyon Co, printers 1916).

The bridge is comprised of 4 independent spans carrying Route 250. Span 2 is the movable truss over the Erie Canal, Spans 1 & 3 are fixed spans over the machinery pits, and Span 4 is over the Erie Canalway Trail.

The lift bridge crosses the canal at a 32-degree skew and on a 4 percent grade. The truss sits on concrete abutments and is 177' long overall and 37' wide between curbs. The bridge weighs nominally 730,000 pounds and can be raised 129” providing a seated clearance of 6' and a raised clearance of 15.75’ above the mean navigation pool. The lift span deck utilizes steel grid with strategic concrete fill at each end to provide coverage over the pier and lifting beams. The machinery pits at each end of the bridge were originally covered with cross-hatch plate covers but have been subsequently changed out to concrete slabs. Riveted-steel stairways at either end of the east side of the bridge provide pedestrian access even when the bridge is raised. The pedestrian walkway is lined with a decorative steel balustrade.

The lift bridge was completed in 1913 and has undergone several rehabilitations and repairs over the years. When originally constructed, the lift span featured an irregular ten sided design with unique interfaces at each approach due to its skew geometry as well as to accommodate a cantilevered approach to West Avenue at right angles to the main structure at the SW corner of the lift span, which is evident at lower right in the above photo. The cantilevered approach was eliminated circa 1987 when urban renewal changed the area; modifications to the truss and counterweight were performed at this corner to accommodate the change in balance of the structure along with other repairs. A painting contract was performed in 1993 and a mechanical and electrical rehabilitation was performed in 1998. Structural deficiencies have been documented since that time through the NYSDOT biennial inspection program causing red, yellow and safety flags to be issue. An interim emergency repair was performed on the lift span deck in 2013 in response to structural deficiencies. However, subsequent continued widespread deterioration led to reduced load carrying capacity causing the structure to be listed as an ‘R-Posted’ bridge, as well as an outdated and failing electrical control, operating system, and machinery that was reaching the end of its service life and did not comply with code requirements.

Project Description

In response to the above deterioration, the subject project was initiated to perform a multi-discipline rehabilitation to strengthen the bridge to meet current code requirements while adopting new technologies as appropriate to improve the efficiency, usability, safety, and reliability of the electrical and mechanical drive and control systems. The project objectives included:

- Addressing the structural deficiencies in order to restore the legal load-carrying capacity for 20 years without load posting.
- Minimize required maintenance
- Update the controls, electrical, and mechanical systems.
- Maintain and preserve the historically significant lift bridge and control tower.

To meet these objectives, the scope of rehabilitation work consisted of structural, mechanical, electrical, architectural, and highway/ITS improvements. Structural work involved the installation of a new galvanized steel open grid deck, stringer and floorbeam replacement, steel repairs to the trusses including bottom chord replacement, cleaning and painting trusses, replacement of the approach spans (pit roof slabs), replacement of the machinery support structure, replacement of the bridge counterweights, concrete repairs to the pits, and replacement of canalway trail underpass tunnel top slab. Mechanical work consisted of replacing the span drive machinery (motor, brakes, reducer, rack and pinion, bearings, and shafts), replacing the operating rope system (operating ropes, take-ups, idler sheaves, anchorages) and replacing the span support system (counterweight ropes, take-ups, counterweight sheaves, trunnions and bearings, and live load supports). Electrical work consisted of replacing the bridge control system including the operator’s control console, upgrading the electrical service to the bridge, providing a power connection for a back-up generator, replacing the navigational lighting, installing architectural lighting, and upgrading the Closed Circuit Television (CCTV) system. Architectural work consisted of replacing the windows, flooring, doors and light fixtures, painting the interior walls and ceilings, and plumbing upgrades inside of the control house. Highway work on the project entailed roadway and sidewalk reconstruction, traffic signal installation and landscaping.

Project Members

The primary project members were as follows: New York State Department of Transportation is responsible for the roadway and administered the project. New York State Canals Corporation is responsible for the operation and maintenance of the lift span mechanical and electrical systems. The prime consultant for the work was Bergmann out of their Rochester, NY office. Wiss, Janney, Elstner Associates, Inc. provided the engineering for the mechanical and electrical systems. Additional team members include Popli Design Group and Watts Architecture & Engineering. The Primary Contractor for the construction was Hohl Industrial, Inc. out of Tonawanda, New York. Hohl performed the structural and mechanical work, and engaged Ferguson Electric for the electrical work.

Design Considerations

The project is located in a village setting bounded by buildings and the Erie Canalway Trail on the north side, the control house on the southeast quadrant, and a town park/gazebo on the southwest quadrant. This results in limited space for staging materials and equipment for construction, as well as restricting the overall approach to the work.

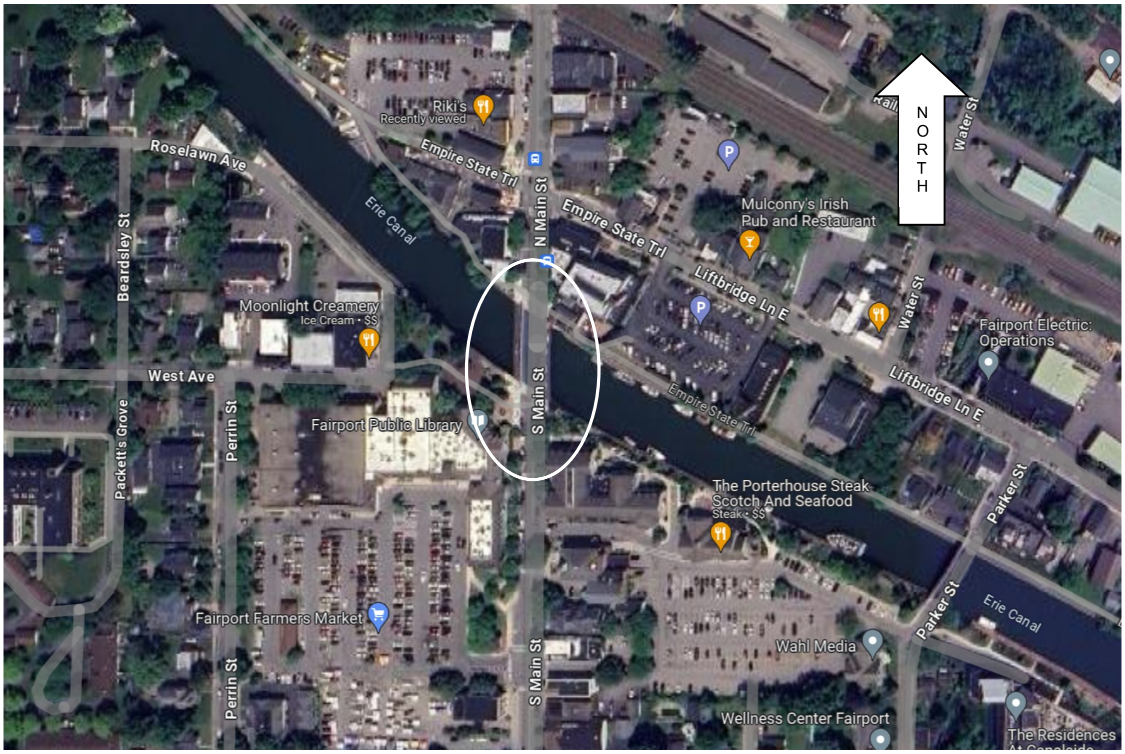


Figure 2 – Area Map locating the Fairport Lift Bridge (photo credit: Google maps).

In addition to these site constraints, the bridge features complex geometry as it has a 32° skew, 4% longitudinal grade, and is asymmetric. As a result of the site and geometry complexities, the rehabilitation was completed with the bridge in the raised position and temporarily supported for a majority of the project.

This added complexities as a significant portion of the existing structural steel required replacement. Only the top chord, diagonals, four lifting posts, and two lifting beams were retained and repaired; all other members (floor beams, stringers, bottom chords, lateral bracing, steel roadway and sidewalk decks, sidewalk brackets, sidewalk floorbeams, machinery supports, and end lifting frames) were fully replaced with galvanized steel. Temporary post-tensioned tie rods were installed between the end posts of the truss during construction to facilitate the staged replacement of the bottom chord of the truss. This ensured the bottom chord could be replaced under near no-load conditions.

Figure 3 – Aerial View of framing during rehabilitation illustrating skew geometry.

Due to the historic nature of the structure, the aesthetics of the final structure needed to match the existing structure. Replacement of the existing steel in-kind or with very similar details was required, as was painting a majority of the new (visible) galvanized steel.

The lift span is raised and lowered via wire operating ropes. Unlike at the other canal bridges which utilize gearing to directly drive the lift posts at one end of the lift span and utilize operating ropes to passively pull the opposing lift posts, the rope system at the Fairport lift bridge directly drives both ends of the lift span. This operating concept is preferable from a mechanical perspective as it affords direct control of each lift post, however, due to the bridge skew and implementation of the drive machinery in an asymmetric location, both longitudinally and transversely, it creates challenges with respect to span balance and rope stretch. Additionally, the original design utilized a minimalist design where the operating rope system was effectively built into the bottom chords of the truss and all other drive machinery was kept within the limits envelope of the truss where it was not visible. In order to maintain the historical character of the structure, very close coordination between the structure and machinery was required to ensure successful implementation as components were modified and/or upsized to meet current code requirements.

The outdated electrical operating system was replaced with a new relay logic control system and Variable Frequence Drive (VFD). The relay logic control system was designed specifically to control how the bridge operates including energizing/de-energizing the motor, setting/releasing the machinery and motor brakes, changing traffic and navigational signals as well as sounding warning gongs. The control system incorporated safety interlocking to ensure that the bridge was operated in the proper sequence and that all safety measures are in place prior to movement of the lift span. The control system provides real-time monitoring of the bridge as it moves up and down, with relevant information relayed back to and displayed on the bridge operator's control console. The design also incorporated redundant VFD's to control the speed of the motor and corresponding movement of the bridge. Of particular note, the design specified a sequence for the VFD to ramp down bridge speed and bring the bridge to a controlled stop at full closed, with the option to adjust the holding torque at seating. This feature, in combination with an improvement to the live load support design to incorporate a shimmable interface, directly addressed a pre-existing problem with inconsistent seating of the lift span and problems with the span floating under the live load of traffic.

A fundamental principle of movable bridge design and operation is bridge balance, specifically, that the total weight of the counterweights 'balance out' the weight of the lift span to limit the required operating force and corresponding electrical demands imparted on the machinery and electrical drive system. Due to the comprehensive rehabilitation of the superstructure, replacement of the machinery and electrical system, and addition of architectural lighting, the overall lift span weight was increased and bridge balance was a significant consideration throughout design. Extensive coordination was required to ensure that the new counterweights were correctly sized to account for the proposed weight of the rehabilitated lift span and that the new counterweights fit within the existing counterweight pits.

Design Features

The project scope encompassed the complete replacement of the operating and support systems as well as a comprehensive rehabilitation of the lift span superstructure which items would render the lift span inoperable for considerable time. The contract documents required that navigation not be impeded by the construction work and provided the option to either complete the work with the lift span in the raised position or to remove the lift span. The documents also specified that the lift span be weighed at different times during construction with load cells to gain precise weight measurements so that the new counterweights could be properly sized. The contractor opted to support the lift span in the raised position and provided temporary support frames that were under each end of the lift span. To address the unique challenges with achieving the required span geometry considering the high skew and change in elevation due to the four percent grade, the temporary support frames incorporated jacking points at each end post. The jacking points allowed independent adjustment at each corner to obtain the proper longitudinal grade and transverse slope and also facilitated installation of load cells for span weighing.

Figure 4 –Jacking Column for Span Support

Photo: N. Jackson

Figure 5 –New Counterweight at Interim Stage of Construction

New counterweights were required to offset the weight of the rehabilitated lift span. The design maintained the use of concrete counterweights, which suited the damp environment in the counterweight pits. The overall counterweight dimensions were dictated by the limited space in the counterweight pits and closely matched the existing dimensions; the counterweights are closely bounded on all sides and there is minimal clearance for overrun on the top or bottom due to the machinery beams above and the pit floor below. As a testament to the close tolerances, at the North counterweight pit, a pre-existing problem had been identified with the counterweight rubbing the pit side wall during operation. One goal of the rehabilitation was to eliminate this interference. In order to achieve the necessary counterweight density to offset the new span weight while maintaining the required clearances, steel ballast in the form of rolled steel beams and steel ballast plate were embedded in the concrete at strategic locations to provide additional weight and provide for transverse weight distribution. The new counterweights were formed up and poured in place in each counterweight pit. The contract documents specified two separate concrete pours for the counterweights. Following the first pour, the lift span and partially completed counterweights were weighed and adjustments to the amount of embedded steel plate ballast in the second pour were made to achieve the balance condition.

A full site survey was performed to establish and monitor span position throughout construction. The survey identified that the actual locations of the counterweight pits relative to one another do not comply with the original plans and that the width of the pits also varies from the plans. In addition, the survey identified that the lift span was shifted to the north relative to the existing pit locations. These findings explained the pre-existing clearance issues at the north counterweight and the southwest lift post lower deflector. The counterweight dimensions were subsequently modified to improve the clearances with the pit walls; the north counterweight was narrowed by 6” and the south counterweight was narrowed by 4”. The lift span position was shifted to its correct theoretical location. The contract plan relationship of the counterweight and counterweight sheaves to the centerline of the lifting frame/lift posts was maintained for the adjusted position. The relationship of these components relative to the pits changed due to the skew orientation, experiencing both a longitudinal (1½”) and transverse (15/16) shift. This locational misalignment was addressed by positioning the new machinery beam and trunnion bearing assemblies at their correct location, casting the new counterweights at their correct location, and then allowing gravity to shift the position of the lift span back to its proper position during the de-jacking process, as the loaded counterweight ropes equalized on the plumb line extending from the sheave tangent point. Temporary blocking was put in place during the jacking process to act as a safeguard against any sudden horizontal shift of the span as the rope loaded. At the completion of the rehabilitation when the ropes were fully loaded, this work was successful in keeping the north counterweight clear of the pit wall.

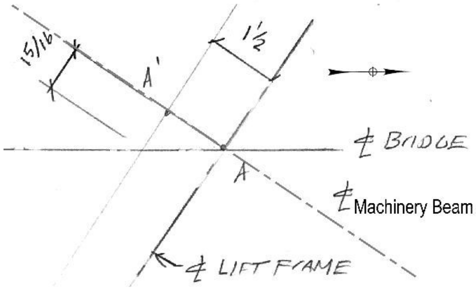


Figure 6 –Shift of Lift Span relative to CL Machinery Beams and CL Bridge

Due to the close integration of the machinery and structure, there was limited ability to upsize components to accommodate additional loading without significantly altering the structure, which was at odds with maintaining the historic character of the structure. Therefore, the mechanical design focused on offsetting the negative impacts of the increased weight of the structure. The main counterweight trunnion bearings support the entire weight of the lift span and counterweights and facilitate movement during span operation. The friction developed at the trunnion bearings is the largest contributor to the span drive power requirements. To mitigate the impact of increased bearing friction due to the increased weight, the design replaced the original sliding type sleeve bearings with roller bearings. This resulted in changes to the support beams and overhead structure (i.e. pit slabs and framing) to accommodate the increased size of the bearings relative to the existing sleeve bearings. In conjunction with an optimized drive ratio, the use of roller bearings achieved a 70% reduction in power requirements, which provided a benefit both to the electrical drive and mechanical drivetrain.

The operating machinery is mounted on the lift span, offset north from midspan and mounted under the east sidewalk. The power for the machinery is provided by an electric motor which drives a parallel shaft gearbox that drives a cross shaft with two pinions. The cross shaft spans the width of the bridge and is supported from the underside of the roadway stringers. The cross shaft drives two pinions which engage racks that connect to the operating ropes. The pinion/rack/operating rope assembly are located at the interior of each truss bottom chord, and the operating ropes run within the chord to the ends of the lift span, where they wrap around span mounted deflector sheaves and terminate at anchorages in the counterweight pit floors and walls. The movement of the operating ropes work to pull the span up or down based on the direction of rack travel.

The rack/pinion and operating ropes are located and move within the bottom chord. Close coordination was required between mechanical and structural to develop the rehabilitation details for these parts. The new bottom chord was strengthened to accommodate the required loading. Countersunk bolts with flush heads and coping of the bottom chord were required at the drive shaft/machinery support locations to accommodate the machinery and ensure adequate clearances.

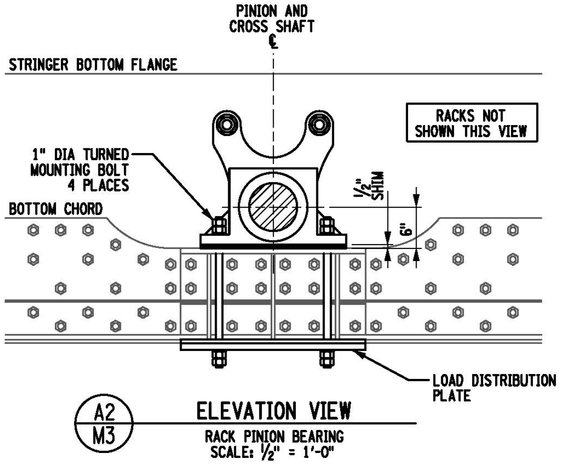


Figure 7a – Rack Pinion Frame Carrier Assembly. Elevation View at Bottom Chord.

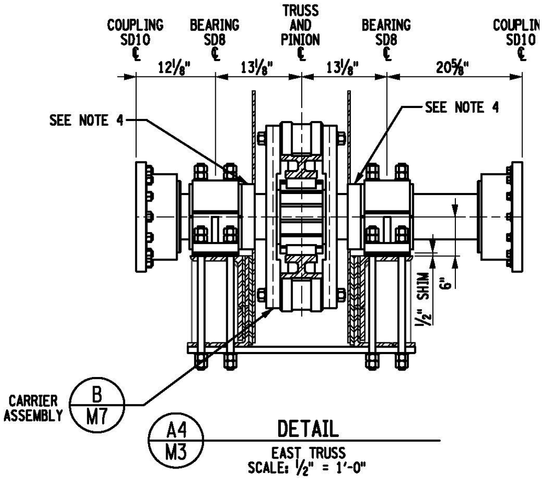


Figure 7b – Rack Pinion Frame Carrier Assembly. View through Truss.

Each pinion shaft engages two racks, one above and one below, and the gearset spacing is maintained via a carrier assembly. The racks have a finite length of travel that corresponds 1:1 with lift height and provides minimal overtravel. Rack length could not be increased to provide additional travel without substantially altering the bottom chord. Due to the finite travel, the racks must be properly indexed in the carrier assemblies upon initial installation to provide for the correct lift height without bottoming out. As pre-existing problems were noted with unequal rack indexing, contract plan details were provided to indicate the exact rack position at the seated and raised positions to facilitate this installation. Once the racks are properly engaged, subsequent adjustments, whether to equalize or adjust loading and/or span position, must be achieved at the operating rope take-ups in the counterweight pits.

Functional Testing

The contract plans required a comprehensive set of operational tests to verify proper installation and operation of the new mechanical machinery, electrical drive, and control systems. Operational tests included a full checkout of the safety interlock system as well as repeatable span operation. Strain gage testing as well as power and amperage recordings were performed during the functional testing to verify that span balance conformed to specification requirements as well as to provide baseline documentation of the operating loads for future reference. The strain gage data was also used to provide direction for control system adjustments to meet the design objective of ensuring that the lift span was firmly seated against the live load supports with a sustained torque at the conclusion of each operation.

Lastly, as part of commissioning, the lift span was subject to a load test to demonstrate that the as-installed equipment had the capacity to operate under the maximum loading required under AASHTO''s external loading requirements for sizing prime movers. External ballast was uniformly added to the bridge deck in several increments up to a maximum of 36 kips. The testing demonstrated that the total operating loads for the maximum imbalance condition were under 80% of full load motor torque indicating that all loads were well within machinery design capacity.

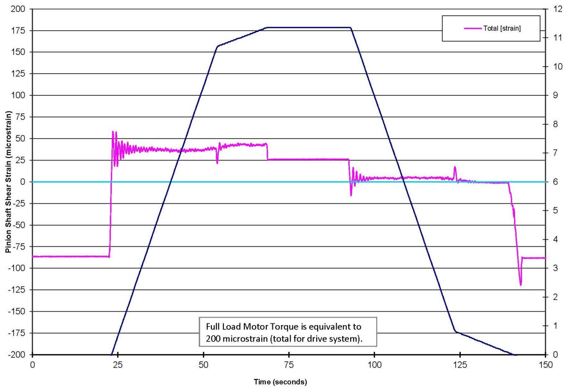


Figure 8a –Normal Operation with Seating Load

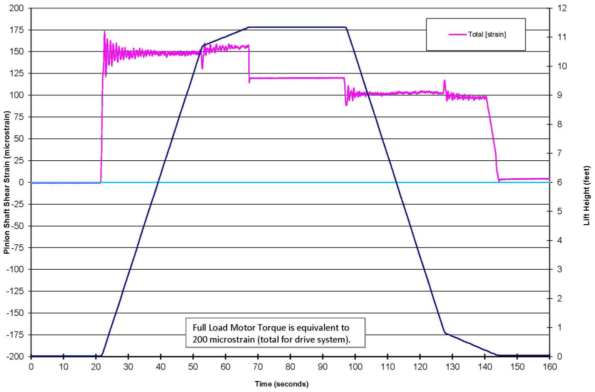


Figure 8b –AASHTO Load Test Compliance - Max Loading

The load test data also demonstrated that the load distribution between the two drive pinions increased with applied load.

Iconic Lighting

Architectural bridge lighting was added to the project in conjunction with New York State's "Re-Imagine the Canals" program. The iconic lighting include illuminating the truss chords and diagonals above the roadway along with under-bridge lighting. Special attention and detailing was required to hide the fixtures in the truss top chord gusset plates and to provide glare shields for the under bridge lighting. Additionally, the weight of the lighting and supports had to be factored into the bridge balance calculations to meet the project balance requirements. The lights are programmable high-efficiency LED luminaires that can be operated remotely and can change color to observe holidays or other theme.

Figure 9 – Fairport Lift Bridg. Iconic lighting.

Figure 10 – Fairport Lift Bridge. Iconic lighting display for holiday.

SUMMARY

The construction costs totaled just under $9,800,000 when awarded in 2019. Construction was complete and the bridge was fully commissioned at the end of 2021. The project successfully accomplished an extensive rehabilitation that retained the historical character of the bridge, extended its service life for years to come, and added visual appeal to benefit the character and charm of the village.

ACKNOWLEDGEMENTS

Bridge Owner, Contract Administrator:
New York State Canal Corporation, New York State Department of Transportation

Engineer of Record:
Colliers Engineering & Design (formerly Bergmann), Wiss Janney, Elstner Associates, Inc.(formerly Stafford Bandlow Engineering, Inc.)

Prime Contractor:
Hohl Industrial Services, Inc.

Machinery Fabricator and Installer:
Hohl Industrial Services, Inc. and Subcontractors

Electrical Contractor:
Ferguson Electric, Inc.

Electrical Controls:
Champion Controls