HEAVY MOVABLE STRUCTURES, INC.
TWENTIETH BIENNIAL SYMPOSIUM

October 7-10, 2024

Glimmer Glass Bridge: A Moving Piece of History – A Comprehensive Guide to Preservation Techniques for a Uniquely Historic Structure

Joseph R. Strafaci, PhD, PE. MBA
HNTB Corporation

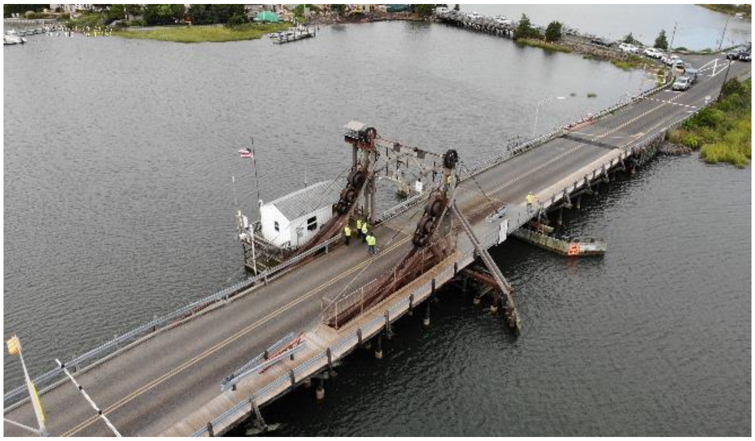
Michael Ruggerio, PE
HNTB Corporation

SHERATON HOTEL
NEW ORLEANS, LA

Abstract

Bridge W-9 (the Glimmer Glass Bridge) is located on Brielle Road/Fisk Avenue in the Boroughs of Brielle and Manasquan. The bridge spans the Glimmer Glass and is one of three routes into Manasquan Beach and can be found on the National Register of Historic Places since 2008. The bridge consists of a single leaf bascule span with 16 laminated timber deck approach spans supported on timber pile bents with a total length of 279 feet. What makes this bridge unique, is its movable span. The span consists of a single leaf bascule with a portal frame that has a curved track on the back span. The bridge operates using a unique rolling counterweight design in which is operated by a motor/gear drive mechanism that drives a cross shaft mounted atop the portal frame. Constructed in 1938, the bridge is nearing the end of its service life and is currently undergoing a scoping study to determine next steps. The purpose of this paper will be to review the efforts the County has taken over the last decade to keep the bridge in service to the public. Efforts include a finite element study, a balance analysis, as well as various rehabilitation efforts.

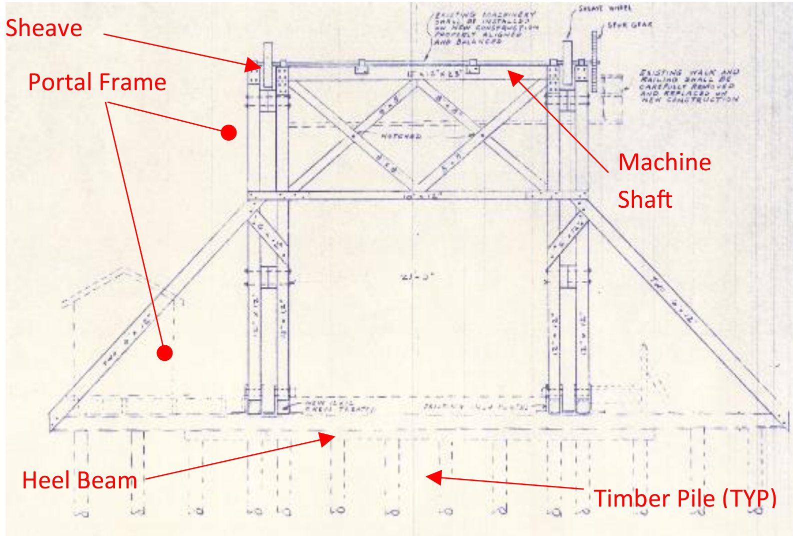
Introduction



Glimmer Glass Bridge (Looking Southwest)

Bridge W-9 (the Glimmer Glass Bridge) is located on Brielle Road/Fisk Avenue in the Boroughs of Brielle and Manasquan. The bridge spans the Glimmer Glass and is one of three routes into Manasquan Beach. W-9 consists of a single leaf bascule span with 16 laminated timber deck approach spans supported on timber pile bents. Each approach pier consists of a timber pile cap supported by six 14-inch timber piles. The total length of the bridge is 279 feet. The overall out-to-out width of the span is approximately 30 feet, including a sidewalk and parapet. The curb-to-curb width varies from the approach span to the bascule span. The approach roadway consists of a roadway on fill between two tied-back bulkheads. W-9's movable span is classified as a rolling counterweight single leaf bascule style structure. Truly unique, the span has a portal frame with a curved track on the back span for the rolling counterweights. The span is operated by a motor/gear drive mechanism that drives a cross shaft mounted atop the portal frame. Two sheaves are driven by this shaft, one at each leg of the frame with a wire rope that wraps around the respective sheave. The rotation of the sheaves causes the movable span and rolling counterweights to be raised or lowered by movement of the wire ropes. The frame is further supported by a series of stay "guy" rods and is mounted onto a steel beam (heel beam) that provides support to the main portal frame, bascule span, tender house, as well as a portion of the eastern approach span.

Due to the condition of the superstructure and substructure, the bridge has been load posted for 3 tons. Additionally, given the configuration of the portal frame, the bridge is posted for a vertical clearance of 10'-0". When out of service, roadway users must use a detour route. The route is approximately 3 miles in length. The detour route shown is the same one emergency and overweight vehicles must use on a regular basis.



Bascule Span Portal Frame Elevation View (1957)

For over several decades, HNTB has been the on-call consultant to Monmouth County for their movable structures. Included in this role has been maintaining the state of good repair of the Glimmer Glass Bridge, while replacement plans are in the work. Given the challenges the County faces (to be discussed in the following section), plans for replacement have been delayed. Mainly due to the bridge's historic significance. This has led us to perform a variety of analyses, prepare rehabilitation plans, even interacting with the public on the occasion as an extension of County staff. This "out-of-the-box" thinking, and approach is the purpose of this paper. First, we will review the current challenges the County faces regarding the bridge. Following this we will review the timeline of construction and physical work performed on the structure. Then we will review the various analyses undertaken over the last five years to better understand/manage the bridge. Finally, we will have some concluding thoughts on the future of the bridge and next steps.

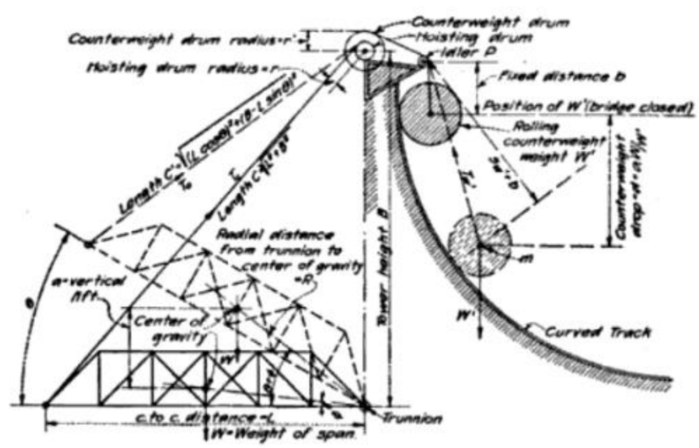


FIG. 9.

Image Depicting a Rolling Counterweight Bridge (Hool, 1923)

Challenges

Given its age, historical significance, unique design and location, Monmouth County faces many challenges when it comes to maintaining the Glimmer Glass Bridge. For starters, the Bridge is nearing 100 years of service, is in serious condition and consists mainly of timber. This dangerous combination puts the bridge very close to the end of its useful service life.

While the County has down-posted the bridge to 3-tons to extend the service life as much as possible, this restriction re-routes emergency vehicles looking to access homes adjacent to the structure. This detour adds another 10 minutes in many cases which in an emergency could mean life or death. Additionally, due to the physical constraints at the bascule span (less than 20 feet), there have been numerous accidents in which vehicle users have lost side view mirrors. Fortunately, due to the low speed over the bridge a more serious accident hasn't occurred.

The current operation time of the bridge is around 15 minutes per cycle delaying pedestrian, bicyclist and motor vehicles looking to access Manasquan Beach. During the summer (the bridge's peak season) the bridge tends to open at least twice an hour closing the road a half hour every hour stranding/delaying users. To compound this, the area falls below the flood plain to the east and during moon tides, Brielle Road floods leaving those to the east completely stranded.

Most notably, the bridge is on the National Register for Historic places and has strong public support via the Save the Glimmer Glass Committee. This organization is committed to rehabilitating or keeping the bridge, and intent on squashing any plans to replace the structure. This has delayed plans for replacement resulting in "out-side-the-box" thinking to develop solutions/strategies to keep the bridge open to vehicular and pedestrian traffic while a replacement solution is designed.

Timeline of Construction/Work

The Glimmer Glass was originally constructed in 1938. This is supported by the NBIS inspection report, and various records in the County's archives. Including a photograph from the Manasquan Record showing the bridge under construction on August 19, 1938. Following its initial construction, W-9 was raised approximately 5 feet at the navigation channel in 1949 resulting in the reconstruction of timber pile bents, bulkhead roadway approaches, and the tender house.


MANASQUAN RECOR
"The Family Newspaper"
MANASQUAN, N. J., FRIDAY, AUGUST 19, 1938

"Big Sea Day" Here Is Colorful Event

Crowd assembled at Brielle road drawbridge, dedicated as opening event on "Big Sea Day" Program.

Manasquan Record, August 19, 1938 showing the Glimmer Glass Still Under Construction

In 1957 the timber portal frame was completely replaced. This project also included replacement of the rolling counterweight track system, cables, yoke, and tie rods and the dismantling of the existing machinery relocating it onto the new portal frame. In 1962, the bascule span timber decking was replaced with a steel grid deck. All other steel elements of the span were painted.

In 1971, the timber superstructure and counterweight track structure were removed and replaced. Under this same contract, the operating machinery was also replaced with a new electric driven motor, controls, and enclosed gear drive assembly. Up until this point, the bridge was manually operated by a crank. In 1981 due to a shear failure in the northern portion of the drive shaft, the counterweights and shaft were replaced. Following this, the bridge began to deteriorate severely specifically the Bascule Span leading to the current 3-ton posting of the structure.

To address issues with the Bascule Span, the County rehabilitated the bridge in 1994. Under this contract, the bascule span was strengthened and rehabbed. This work included replacement of the steel grid deck, stringers, angle seats, and sidewalk bracket. The fascia beams and floor beams remained in place and were cleaned and painted. This contract also included repairs to the timber fender system, upgrades to the existing electrical system, replacement of the warning gates, span locks, barrier gate, and submarine cable.

Elevation View of the Glimmer Glass in 1970's

In 2004, the County made repairs to the bascule span operating machinery. Under this contract, the County replaced the operating ropes, tightened the tower stay rods, replaced the babbitt bearings, adjusted the machinery alignment, and secured the counterweight tread plates. In 2006, County DPW forces installed the traffic gate gong. Following this, due to deterioration to the laminated timber deck, County forces also installed temporary steel plates throughout the bridge and repositioned "jumped" the span wire ropes to prevent overlapping due to slippage and wearing of the sheaves.

Glimmer Glass under Construction during 2014 Deck Replacement

In 2009, the County issued a repair contract to address NBIS Priority 1 and 2 repairs specifically at the fender system. In 2010, the County replaced the trunnion bearing pins located at the heel of the bascule span due to issues during operation. Following this, in April 2014, the traffic warning gate was replaced by County forces due to the existing unit malfunctioning and showing signs of deterioration.

In August 2014, an overweight vehicle damaged the laminated timber deck beyond repair, closing the bridge. In response to this, the County replaced the laminated timber deck on both approaches in-kind and jacketing approximately half the timber piles due to significant marine borer damage. This work was completed in eight months and open in time for the 2015 summer season. To avoid another similar incident, the County in June 2015 installed surveillance equipment. However, due to the condition of the portal frame which was not repaired under the 2014 contract the intermediate bearings located on the top chord became dislodged from the timber chord in August 2015 which the County needed to temporarily bracket to hold in place.

In Fall 2017, inspectors discovered the remaining unjacketed timber piles were in critical condition with most having an existing diameter of less than 4 inches (the original diameter was 12 inches for reference). This resulted in another eight-month closure of the bridge so that the remaining piles could be jacketed. Additionally, the intermediate brackets were replaced with a more permanent solution. were mechanical repairs to the operation machinery.

Following the 2017 rehabilitation project, the existing Sumitomo Gearbox Reducer malfunctioned during operation breaking in October 2020. This unit, as well as the existing motor, were replaced with a new SEW Euro-drive, updating the existing system to a digital programmable AC motor drive controller allowing more accurate motor speed and torque control.

As the portal frame had not been replaced since 1957, in September 2021, the County reported that the portal frame began to visibly deflect during operation. Additionally, it was also noted that the bascule span was racking during operation. This was remediated in 2023 when additional weight was added to the northwest toe of the span.

Studies Undertaken

Since 2018, the County has undertaken several studies with the goals of better understanding and managing the state of the Glimmer Glass bridge until it can be replaced. Currently, a strategy for replacement does exist. Under the “Three Bridges Scoping Study” the County is in the process of replacing the existing bridge with a new movable of similar design and upgraded materials on the same alignment. As of the most recent update the County is in the process of finalizing the environmental assessment document and awaiting Section 106/NEPA approvals. Based off this it is estimate the bridge will be reconstructed sometime in 2028 leaving the county less than 5 years to maintain the current structure. This is important, as it dictates current and future decisions as how to best manage the structure.

Given this information, the following assessments were performed when it comes to the Glimmer Glass Bridge:

- NBIS Inspection Report Review
- Visual Inspection
- Substructure Dive Inspection
- Timber Material Assessment
- Structural Health Monitoring Evaluation
- Structural Analysis

Physical/Visual Studies Performed

The first study undertaken was a review of the 19th Cycle National Bridge Inspection Standards (NBIS) evaluation report. Per review of this document, the report finds that “the overall condition of the structure is critical due to low inventory ratings. The overall physical condition of the structure is poor due to the condition of the superstructure” (NBIS 2021), specifically the bascule span girders and floorbeams. The bridge superstructure is structurally deficient and functionally obsolete due to substandard deck geometry. Under the SI&A Sheets, the bridge has a sufficiency rating of 9.6 (out of 100). The bridge is rated/posted for 3-tons because of the H20 truck inventory analysis. Additionally, the mechanical, substructure and electrical condition were also inspected. The electrical components were found to be in good condition, while the mechanical system was found to be in fair condition, meanwhile the substructure was found to be in fair-poor condition due to the amount of work performed.

Following this, in January 2022 performed a follow up inspection concurring with much of the NBIS inspection report. The bascule span was found to be in an advance deteriorated state with section loss ranging from 10-50% with areas of 100% section loss noted in several locations. The Portal frame, heel beam, approach and mechanical system were also inspected. Per this inspection, the portal frame deflects during operation with crushing noted on southern tower. The heel beam which supports the entire bascule span and frame is in an advance deteriorated state, with parts of the flange and web exhibiting up to 100% material section loss. The mechanical system was found to be in poor condition with most of the elements worn down and in need of replacement. The approach on the other hand was in better condition mainly due to the 2014 rehabilitation, but the sheet piles which hold together the viaduct approach show signs of significant section loss resulting in roadway settlement.

The next study performed as a subsurface dive inspection. Performed by Churchill Engineering, several of the pile jackets installed in 2014/2018 had cracked leaving 5 to 8 years of viable service life left. However, no scour or undermining of the pile jackets had been noted. Overall the substructure was found to be in fair to poor condition, but lacked a strategy for repair once the pile jackets were deemed to be no longer effective.

Additionally, a timber material inspection was also undertaken. Performed by Wood Science Consulting wood cores were taken from the portal frame, pile caps, and timber piles to approximate the remaining service life and identify areas of decay. Per this analysis, it was determined that the remaining service life is around six years with the worst areas of timber decay occurring at the southern column of the portal frame.

Advanced Analysis Performed

To further diagnose issues occurring at the Glimmer Glass Bridge, nondestructive testing was performed. This was in response due to issues as they relate to the racking of the span during in operation; deflection of the portal frame; physical condition of the heel beam; and concerns related to the load carrying capacity of the bascule span. In response to these concerns a Finite Element Model was developed in conjunction with a Balance Evaluation; Hoist Cable Force Analysis; and standard Live-Load Testing were performed. Using this information of Load Ratings were run for a variety of vehicles which could potentially traverse the structure.

For the balance evaluation, sensors were placed on various elements of the bascule span and its operation machinery. Per this evaluation, it was determined that: The north side of the span is only slightly span heavy while the south side of the leaf was span heavy by approximately 1.71 kips; Minor racking and twisting of the span/tower occur during operation per the portal frame sensor and span rotation responses; during operation, the top of the south tower rotates towards the span, resulting in significant bending when compared to the north tower, which did not have a response; and there is a varying lifting behavior between sides at the start of operation but lifting speeds do equalize during operation under a slightly racked condition. These findings, were consistent with visual observations, and results regarding this analysis are shown in the below table:

Table 1 - Balance Evaluation Results

Leaf Element	Imbalance Moment (Kip-Ft)	Center of Gravity Angle (Degrees)	Horizontal Imbalance Moment (Kip-Ft)	Vertical Imbalance Moment (Kip-Ft)	Toe Reaction at Seated Position (Kips)	Maximum Leaf Frictional Moment (Kip-Ft)
Total Leaf	193.12	-67.31	74.5	-178.18	2.12	26.32
North Side	18.40	-47.20	12.5	-13.50	0.36	16.41
South Side	174.63	-69.90	60.0	-164.00	1.71	15.00

For the hoist cable force testing, accelerometers were placed on both the north and south hoist cables on the span sides. The purpose of this testing was to collect cable vibration frequencies to estimate cable forces during operation results are shown in the below table:

Table 2 - Hoist Cable Force Testing Results

Bridge Position	North Fund. Freq. (HZ) during Lifting	South Fund. Freq. (HZ) during Lifting	North Fund. Freq. (HZ) during Closing	South Fund. Freq. (HZ) during Closing
Fully Closed	6.59	5.7	6.61	5.61
Mostly Closed	6.62	6.26	6.58	6.26
50% Open	6.86	6.70	6.88	6.71
Mostly Open	6.99	6.99	6.93	6.99

As shown above, the north cable starts with a higher frequency than the south. This indicates that the force on the north side is greater than on the south at this point. As operation continues, the frequency begins to even out and is equalized at the “mostly open” position. This table in conjunction with the balance analysis performed provides further indication of an imbalance between the north and south sides of the bascule span. This is potentially a reason for the southern column rotating excessively during the initial lifting of the span.

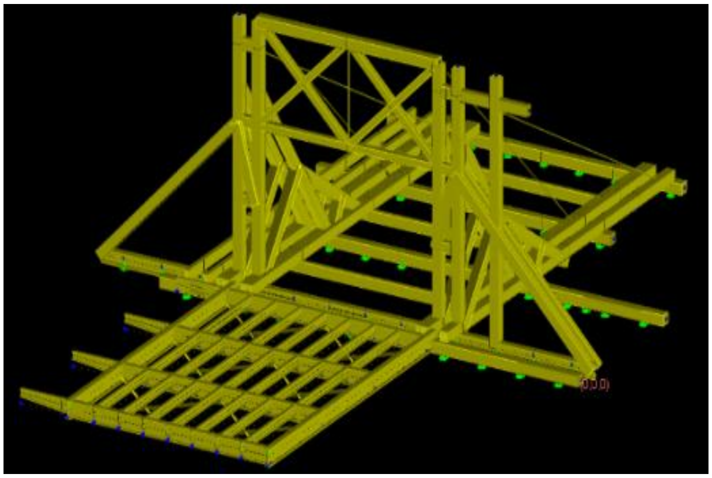
Next, a series of load ratings were performed, specifically at the bascule span to evaluate member capacity. To achieve this, the existing NBIS inspection report was first reviewed to find the controlling member for the bridge. Per the report, the bascule span fascia girders (20Ix65) was determined to be the controlling member.

Load ratings of this girder were performed following the 2018 AASHTO Manual for Bridge Evaluation. Given the unique nature of the span, the member was rated following the Strength I method, looking at vehicles ranging from a pickup truck of known weight to HS-20 and HS-25 design loadings. Additionally, the fascia girder was evaluated using the Manasquan emergency vehicles. Information regarding the vehicle weight and axle spacing was provided by the County. These results are shown below:

Table 3 - Load Rating Analysis Results

			As Built		As Inspected	
Owner	Type	GVW (Tons)	INV	OP	INV	OP
Monmouth County	Pickup	3.8	2.4	3.0	2.2	2.8
Monmouth County	Heavy Pickup	7.6	1.1	1.4	1.0	1.3
Monmouth County	Large Truck	15.5	0.5	0.7	0.5	0.6
MS VEC #2	First Engine	21	0.4	0.6	0.4	0.5
MS VEC #3	Third Engine	16.3	0.5	0.7	0.5	0.6
MS VEC #4	Second Engine	14	0.7	0.9	0.6	0.8
MS VEC #5	Water Rescue Apparatus	5.13	1.7	2.3	1.6	2.1
MS H&L No. 1	Tower Ladder	40.4	0.2	0.3	0.2	0.3
MS H&L No. 1	Engine	23.5	0.4	0.6	0.4	0.5
Design	HS-20	36	0.3	0.4	0.3	0.4
Design	HS-25	45	0.2	0.3	0.2	0.3

As we can see, only the heavy pickup truck, normal pickup truck, and water rescue apparatus pass the load rating check for either the as-built or as-Inspected condition. As for the live load analysis performed by BDI, the Pickup and Heavy Pickup were utilized. Per review of the data provided it was apparent that the Pickup and Heavy Pickup results were inline with load rating calculations. Therefore, in-kind rehabilitation of the fascia girder would not provide adequate structural capacity to safely withstand the heavier vehicular loadings.



Finite Element Model of Glimmer Glass Bridge

Following this, a finite element analysis of the portal frame, bascule span, and heel beam was performed. Using LARSA 4D the model was developed using the geometry and member sizes of the portal frame, bascule span, and anchor span from the original plans, as-builts and/or bridge rehabilitation contract drawings. Wind and live loads were applied to the model and given the structural capacity deficiencies noted, the live load used in the analysis was an H-15 truck (20 tons) in lieu of the typical HS-20 or HL-93 design load. The tension force from the supporting cables were also included.

The bridge is modeled in three stages, one with the bascule span in the closed position, one slightly opened and one in the fully open position. The results obtained from the model (i.e., member forces) were used to evaluate the adequacy of bascule span. Hand calculations were made utilizing these forces to determine the adequacy of the portal frame members.

Based on the analysis performed, it was determined that under H-15 truck (20 tons) loading, the fascia girders are overstressed in the as-built condition and the bridge will remain load posted. Additionally, given the current physical condition of the span and its elements, the current 3-ton posting is found to be appropriate.

Rehabilitation Evaluation

Using the above information, a rehabilitation evaluation was performed. The goal of the evaluation was taking data obtained determine whether a strategy for rehabilitation could be accomplished. If it could not be accomplished develop a strategy to maintain the bridge while a replacement design was advanced. While a rehabilitation assessment is included as a part of the scoping study, this analysis provides additional details and a “third-party” independent review of the facts at hand with the safety of the public and state of good repair for the bridge our primary objectives.

Per the data provided, the bridge rates for 5 tons (inventory) under the HS-20 design loading and only is 6 tons under the as-built condition making it inadequate to meet the HS-20 design load. Under the current AASHTO LRFR design standards, W-9 has a controlling operating rating factor of 0.11 for the SU7 truck. Per the 2018 AASHTO Manual for Bridge Evaluation, a rating factor under 0.30 would result in closure of the bridge to that vehicle.

From a condition standpoint, the heel beam is in critical condition. Defects have been addressed with a variety of stopgap repairs, including timber blocking of the web and the installation of an additional steel channel near the southern columns of the portal frame. Further repair of this member will be difficult, and it is likely that this member will need complete replacement. Replacement of this element will significantly impact the connected elements and has the potential to result in the complete replacement of the entire bascule span and tender house.

Per the WSC Report, the expected remaining service life of timber elements which were not replaced in 2014 is less than 6 years. Per the BDI evaluation, this column bends excessively in comparison to the northern columns. Should this column fail, rehabilitation will be difficult, and replacement will likely be required.

As for the span operation, there is racking between the north and south sides of the bascule leaf. Per the BDI evaluation, the southern sheave performs most of the work during operation in comparison to the north. There is also an imbalance between the south and north side resulting in the issues with seating the northern portion of the leaf when closing. While repairs have been made, it is likely these issues and others will continue to occur. Rehabilitation of these elements is not feasible as it would result in replacement and upgrade of various connected members such as the portal frame.

Based on the above defects, rehabilitation is impracticable as it would result in the replacement of many elements of Bridge W-9. Additionally, in the as-built condition, Bridge W-9 fails to meet the requirements set forth by both the AASHTO LRFD Design Manual and the NJDOT Design Manual for Bridges and Structures. Even with strengthening of various members it is likely the bridge would not be able to service design vehicles, as well as any emergency vehicles. The members exhibiting the greatest deterioration and worst physical condition include the steel heel beam, portal frame, and timber piles with cracked pile jackets. Based on the findings of the various inspections and material testing and monitoring, it is estimated the remaining service life of the bridge to be 6-10 years.

Conclusion

As we can see based off this timeline of work, the Glimmer Glass has gone through multiple iterations of repairs in which some, if not all, members have been replaced in kind. Additionally, repairs performed today have mainly been stopgap measures that allow the bridge to remain in service. Based off the various evaluations the bridge has less than 10 years of service life remaining, and a rehabilitation project would be costly not to mention extensive resulting in most if not all members being replaced.

Based off a review of the timeline of construction the bridge itself is not original with most if not all elements already replaced at one time or another. Meanwhile given pushback by local interest groups, the County has maintained a proactive approach to keep the bridge in service to at least the local traveling public. However, a new bridge is essential in the long term. Given this, the new bridge should meet latest design standards, but also retain the Glimmer Glass's rich history. In conclusion, while the Glimmer Glass is historic, the methods in which the County has gone to preserve the bridge is also in many ways historic. Representing out-of-the-box thinking, and providing innovative solutions to keeping a bridge in service despite its numerous hinderances.

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