Revitalizing Heritage Infrastructure: Preserving the Touchette Bridge's 70-Year Legacy

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Abstract

Egis (formerly Mcintosh Perry) was tasked with extending the service life of the 74-year-old Touchette Bridge over the South Nation River near Casselman, Ontario. The bridge was a 73 m long single-span Parker through truss bridge with a timber deck on steel stringers supported by steel floor beams.

The bridge was in poor condition with severe section loss in the steel floor beams and stringer deck system and extensive delaminations and spalls on its abutments. The poor condition had limited loads on the structure to 15 tonnes and the bridge was on the brink of closing. The Nation, a rural municipality boasting a population of just 13,000 inhabitants and an annual capital works budget of $5 million, sought our expertise to address a critical infrastructure challenge. The municipality had planned to replace the bridge but could not secure sufficient funding to cover the costs.

The stakes were high. Failure to restore the bridge within the available budget would have had profound implications for the local agricultural community. With the nearest alternative crossing located 25 kilometers away, agricultural operations on either side of the bridge would have faced substantial disruptions, impacting both efficiency and livelihoods.

The client tasked us with designing a rehabilitation that would restore normal loading conditions and extend the service life of the bridge by more than 25 years.

During the teams initial site visit, to confirm the scope of work, the bridge team noted a concern with the south abutment which was not previously identified. The south abutment expansion joint was completely closed, and the deck end was pushing against the ballast wall even as the bridge contracted in colder temperatures. In addition, the south abutment uni-directional pot bearings had exceeded their movement capacity and the PTFE sliding surface had become dislodged. Following an assessment of the south abutment, it was concluded that the south abutment needed to be stabilized before removing the entire steel deck system and jacking the truss to replace the bearings.

These unexpected concerns made salvaging the bridge more difficult. This project exemplifies the challenges faced by small municipalities in managing large bridges and the ensuing economic complexities of their maintenance.

This paper will discuss the analysis of the truss and substructure, the stabilization of the abutment and the carefully engineered construction sequence that was developed to complete the $4.5M rehabilitation.

1.0 Background

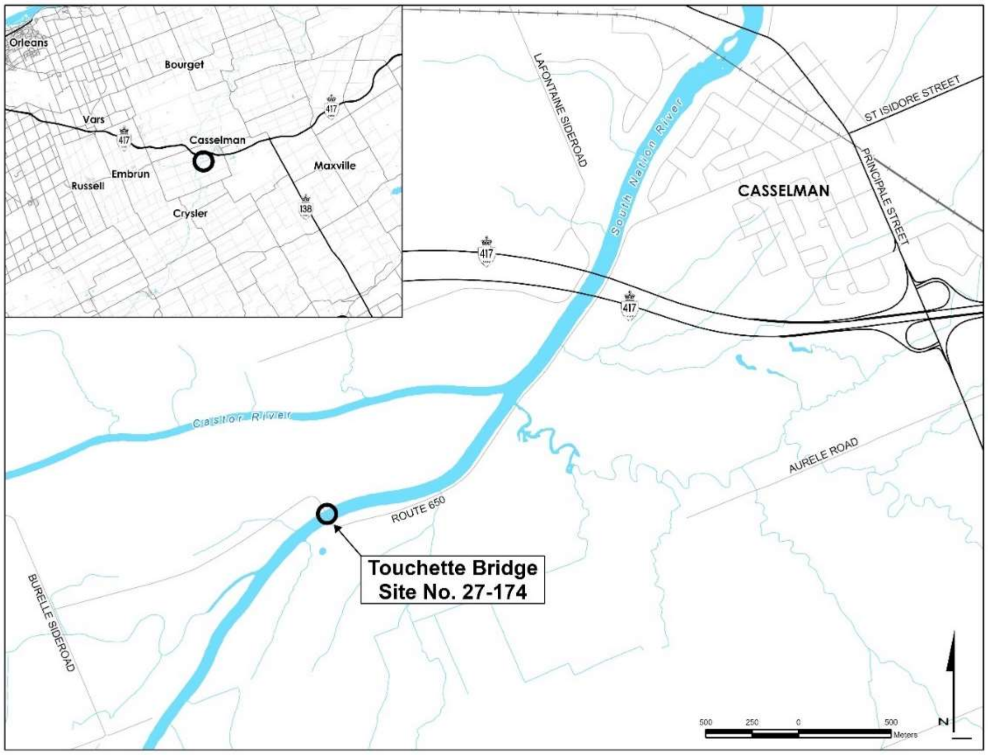
The Nation Municipality entrusted Egis with the task of conducting both Preliminary and Detailed Design phases for the rehabilitation of the Route 650 Touchette Bridge spanning the South Nation River. This rivet-connected historical bridge, stood in a state of disrepair necessitating extensive rehabilitation to prolong its operational lifespan.

The team took on this challenge with short notice and had an aggressive delivery schedule to ensure it could be started in the upcoming construction season.

Flowing through the heart of Eastern Ontario, the South Nation River holds distinction as one of the region's largest waterways. Originating north of Brockville and meandering its way to the Ottawa River, the river's journey traverses leda clays, known for their inherent instability, underscoring the technical complexities inherent in this rehabilitation endeavor.

The bridge is located on Route 650, 3 km southwest of Casselman, Ontario. A key map of the structure location is provided in Figure 1.

Figure 1. Key Map



1.1 <u>Existing Structure</u>

The bridge was constructed in 1950 (71 years old) and consisted of a 73.15 m single span modified Parker through truss bridge with a timber deck on steel stringers supported by steel floor beams. The bridge had an overall width of 7.315 m, with two (2) narrow 3.115 m through lanes, but traffic was observed to be treating the roadway across the structure as a single lane during inspections.

The superstructure was supported by concrete abutments founded on wooden piles driven to an unknown depth complete with expansion joints at each end. Cantilevered concrete wingwalls were provided at all quadrants. Photos of the bridge are included in Figure 2 and Figure 3.

Figure 2. North Elevation View of Bridge

Figure 3. Bridge Deck Looking East

1.2 Rehabilitation History

In 1952, the bridge underwent significant modifications to enhance soffit clearance, necessitating alterations to the existing pedestals and bearings.

Subsequently, in 1995, the bridge underwent a comprehensive two-phase rehabilitation initiative. This extensive effort involved the replacement of the original reinforced concrete deck with a laminated wood deck, the reinforcement of select truss members, the installation of new bearings and replacement of expansion joints.

The new bearings were designed to accommodate thermal expansion and contraction, with two fixed pot bearings installed at the north abutment and two unit-directional pot bearings at the south abutment. Additionally, as part of the rehabilitation efforts, a triple load posting of (21, 33, 40) was implemented.

1.3 Existing Conditions and Needs

The load posting was reduced to 15 tonnes in 2021 based on severe section loss in the floor beams and stringers.

Table 1 summarizes the existing bridge condition and repair needs identified during the site visits.

Table 1. Summary of Bridge Condition and Needs

Element	Condition	Needs
Asphalt	Potholes, cracking throughout	Replacement
Timber Deck	Severe rot	Replacement
Floor Beams and Stringers	Severe section loss and perforations	Replacement
Bottom Cross-Bracing	Severe section loss and perforations	Replacement
Truss System	Light surface rust	Recoating
Interior Portal Bracing	Impact load damage at both ends	Repair
Expansion Joints	Deformations and leakage	Replacement
Abutments	Extensive delaminations and spalls	Refacing
Ballast wall	Extensive delaminations and spalls Deck pushing into ballast wall	**Further Investigation Required**
Wingwalls	Severe disintegration with spalls and corroded rebar	Replacement
Bearings	South abutment pot-bearings out of alignment	**Further Investigation Required**
Embankments	Erosion around bridge	Slope protection

Figure 4 shows the south end of the truss bearing against the ballast wall and Figure 5 provides evidence that the uni-directional pot bearings had exceeded their movement capacity as the PTFE had become dislodged due to excess movement.

Figure 4. Truss Against South Abutment

Figure 5. Dislodged PTFE at South Bearings

The team noted that the abnormal movement could be evidence of a bigger problem and required further investigation.

2.0 Abutment Bearing Assessment

The truss is securely anchored at the north abutment by two fixed pot bearings. At the south abutment, thermal movement is accommodated by two uni-directional pot bearings. The anticipated thermal movement at the south abutment is approximately -55 mm (contraction) and 35 mm (expansion), assuming the bearings were replaced at temperatures ranging from 15 to 20 degrees Celsius.

While previous inspection reports did not raise concerns regarding the bearings, photographic evidence indicated that both the bearings and the deck end have remained in the same position for over a decade. To verify this, the team conducted close-up inspections of the south abutment bearings at two different temperatures: 20 degrees Celsius (in September 2021) and 0 degrees Celsius (in December 2021).

Ideally, the longitudinal position between the upper and lower bearing assembly would have changed as the superstructure contracted in colder temperatures. However, as illustrated in Figure 7 and Figure 8, the position of the bearings remained unchanged despite the temperature drop, indicating a malfunction in their intended functionality. Notably, no abnormal issues were observed with the north abutment's fixed pot bearing.

Moreover, the span between abutments, as measured during the survey, was found to be shorter than the dimensions specified in the original drawings. This suggests that the substructures may be closer together than initially designed for, adding another layer of complexity to the structural assessment and potential remediation efforts.

Figure 6. Superstructure Against South Abutment Ballast Wall from 2012 Winter Inspection

Source: Nation Municipality

Figure 7. South Abutment Bearings in September

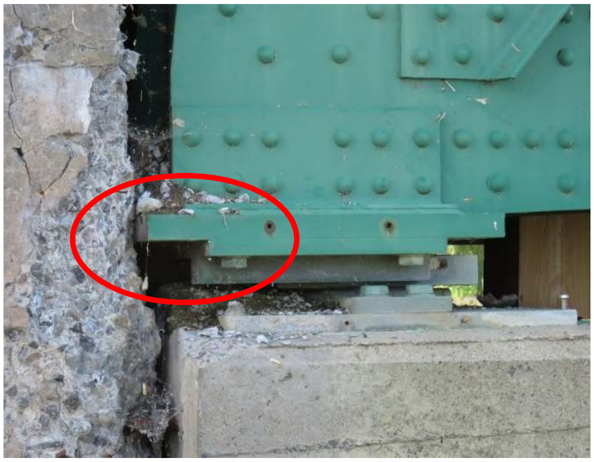


Figure 8. South Abutment Bearings in December

2.1 Summary of Findings

Based on the position of the south abutment and deck end, it appeared that the south abutment had rotated inward toward the water.

The main concern at this point is the stability of the south abutment as it appeared the structure (truss) is bracing the south abutment. To rehabilitate the structure, the south abutment would need to be stabilized prior to any work being completed on the structure.

Additional analysis would be required to confirm why the movement had occurred, but the most likely factors included:

- Failure of piles
- Insufficient lateral resistance of wall and vertical piles (i.e., soft soil).
- No approach slab is present to minimize live load surcharge.

3.0 Key Technical Challenges

Following a comprehensive examination of the original drawings and on-site investigations, several significant technical hurdles emerged:

Abutment Stability: The south abutment had evidently experienced movement, necessitating stabilization efforts before any structural rehabilitation could commence. Addressing this instability was paramount to ensure the safety and integrity of the bridge.

Structure Capacity: It's imperative that the rehabilitation efforts eliminate the load postings on the bridge. This route serves as a crucial artery for local farmers, and restoring its full capacity was essential for facilitating their transportation needs efficiently.

Construction Sequencing: Developing a meticulous construction sequence was vital to prevent further movement of the abutments during the rehabilitation process. Ensuring the stability of the bridge's foundational elements throughout construction activities was critical for the success of the project.

Construction Cost: The financial constraints faced by small municipalities pose a significant challenge in undertaking large-scale bridge replacement or repair projects. In this case, the projected cost of rehabilitating the bridge nearly surpassed the municipality's entire capital budget for public works, highlighting the magnitude of the financial challenge and the need for innovative funding solutions or cost-effective alternatives.

Addressing these technical challenges demanded a strategic approach, combining engineering expertise, meticulous planning, and innovative solutions to overcome budgetary constraints and ensure the long-term viability of the bridge for the community it serves.

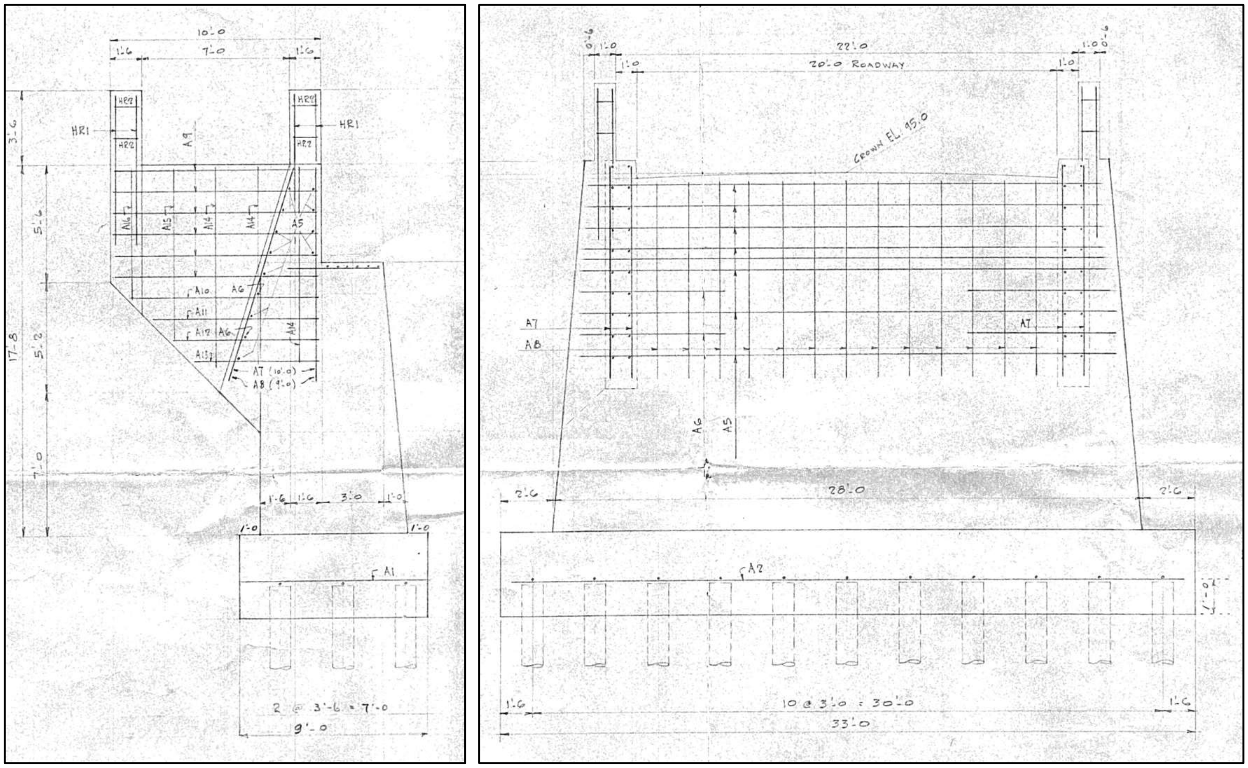
4.0 Abutment Stability

To help determine the source of the abutment movement, an analysis of the existing loads on the abutment and piles was completed using Midas Civil.

4.1 Abutment Configuration

Figures of the existing abutment drawings from the 1950’s are provided in Figure 9. The drawings identified 3 rows of piles spaced at 1.07 m and 0.914 m in the transverse and longitudinal direction respectively. The size or type of pile was not identified on the drawings but based on the year of construction and scale, it has been assumed that it is 12“diameter timber piles driven to an unknown depth.

Figure 9. Abutment Configuration



Source: Nation Municipality

4.2 Analysis

Using Midas Civil (2022) a three-dimensional Finite Element Model (FEM) of the south abutment was created. The model consisted of shell elements that represent the abutment wall, ballast wall, and footing. The timber piles were represented by frame elements. To simulate the interaction between the piles and the surrounding soils, soil springs were incorporated into the FEA model via discrete springs along the pile length.

The purpose of incorporating the springs was to evaluate the movement of the abutment under service loading.

No site-specific foundation information was available during the Design. To complete the analysis, it was assumed that the existing soil stratigraphy consisted of sand overlaying layers of clay. These assumptions were then used for the development of the soil springs.

4.2.1 Load Cases Considered in Analysis

The following loads were considered in analyzing the structural behavior of the abutment:

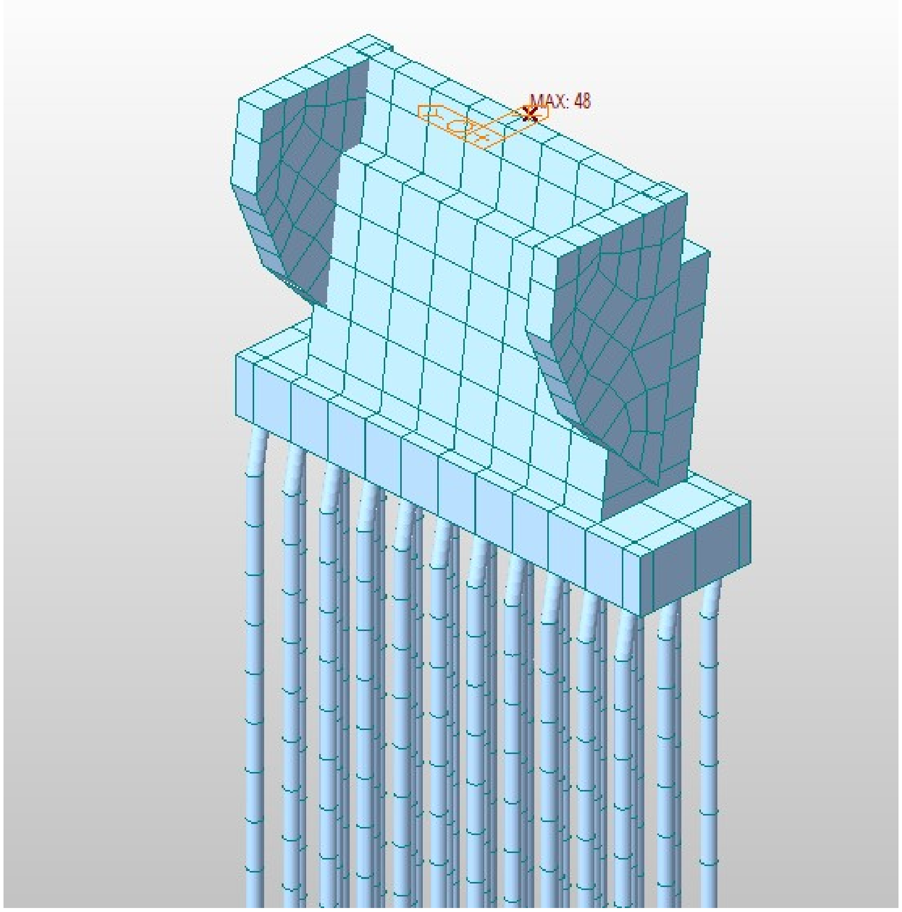
- Dead loads
- Live load (including braking)
- Horizontal earth pressure (Active & At-Rest)
- Compaction & LL surcharge

The combinations of Ultimate Limit State (ULS) and Serviceability Limit State (SLS) were created from the above list of applied load cases.

4.2.2 Analysis Results

The model showed that under active pressure, the top of the abutment rotated in by 50 mm as shown in Figure 10. The lateral resistance provided by the superstructure was ignored as the upper and lower bearing are unrestrained from sliding in the opposite directions.

Figure 10. Abutment Configuration



Based on these preliminary results, it was expected that the insufficient lateral capacity in the wall and piles is likely a primary factor for the south abutment movement. The team recommended to the Municipality that a dead man anchor system be installed to provide additional support.

5.0 Superstructure Evaluation

5.1 Background

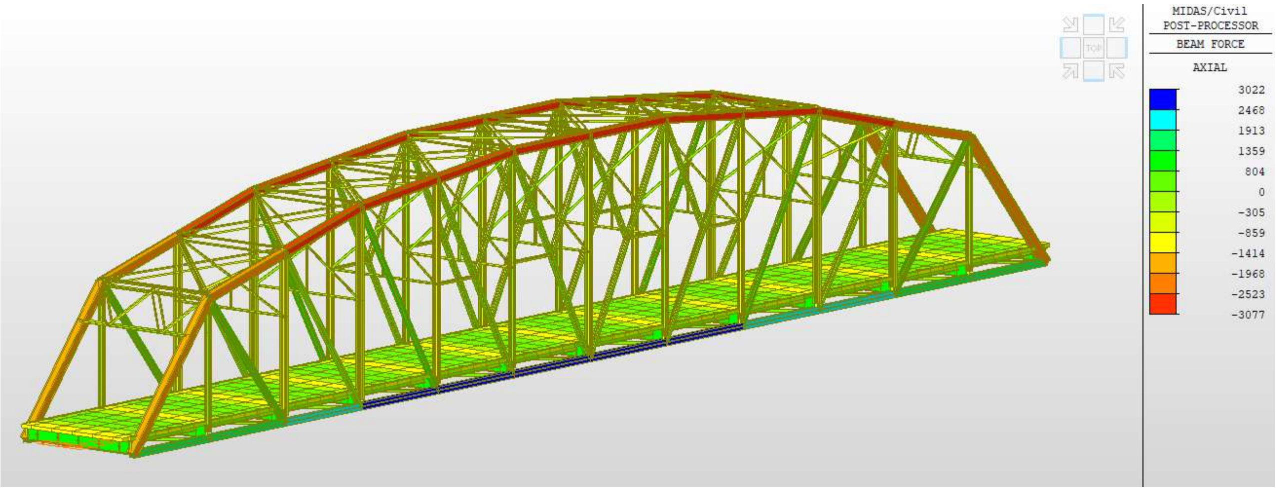
An evaluation of the existing superstructure was completed to confirm the load-carrying capacity of the existing truss members. The truss evaluation was carried out in accordance with Section 14 and 15 of the *CSA S6:19: Canadian Highway Bridge Design Code (CHBDC)*[1].

The current load posting of 15 tonnes was based on the severe corrosion of the floor beams, stringers, and deck.

5.2 Analysis

An analysis of the existing loads on the truss was completed by developing a three dimensions model using Midas Civil (2021). The model, as shown in Figure 11, consists of frame elements that represent the truss and deck system.

Figure 11. MIDAS Model of Truss with Axial Forces at ULS



The analysis indicated that the bridge could accommodate full CHBDC loading if it were reduced to a single lane and outfitted with a concrete riding surface.

Consideration was given to using a lightweight FRP (Fibre Reinforced Polymer) Deck, which offered the advantage of reducing dead load weight while enhancing the live load capacity factor (LLCF) for compression members, but its high cost would have required a significant increase in the budget.

In efforts to mitigate chloride penetration, a standard practice involves applying a 90 mm thick asphalt and waterproofing system on bridge decks. Considering the significance of the bridge to local farming operations, the Municipality prioritized providing full load capacity over installing an asphalt riding surface.

To enhance the durability of the concrete deck, premium reinforcing steel would be incorporated into the top mat of reinforcement. This measure ensures the structural integrity and longevity of the bridge deck under heavy agricultural equipment usage.

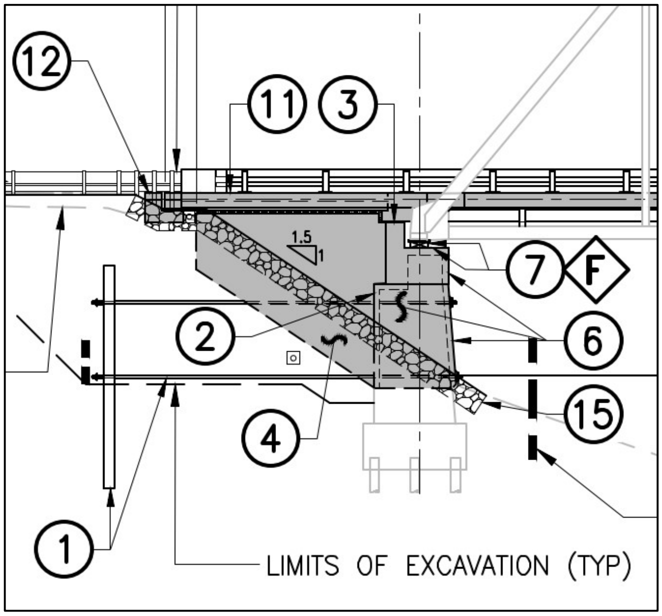
6.0 Recommended Scope of Work

The municipality's decision to rehabilitate the bridge represented a substantial financial commitment. By extending its lifespan by a minimum of 25 years, the municipality aimed to optimize the return on investment, guaranteeing sustained functionality and serviceability for years to come.

6.1 Substructure Repairs

A summary of the proposed substructure repairs is included in Figure 12.

Figure 12. Summary of Substructure Repairs



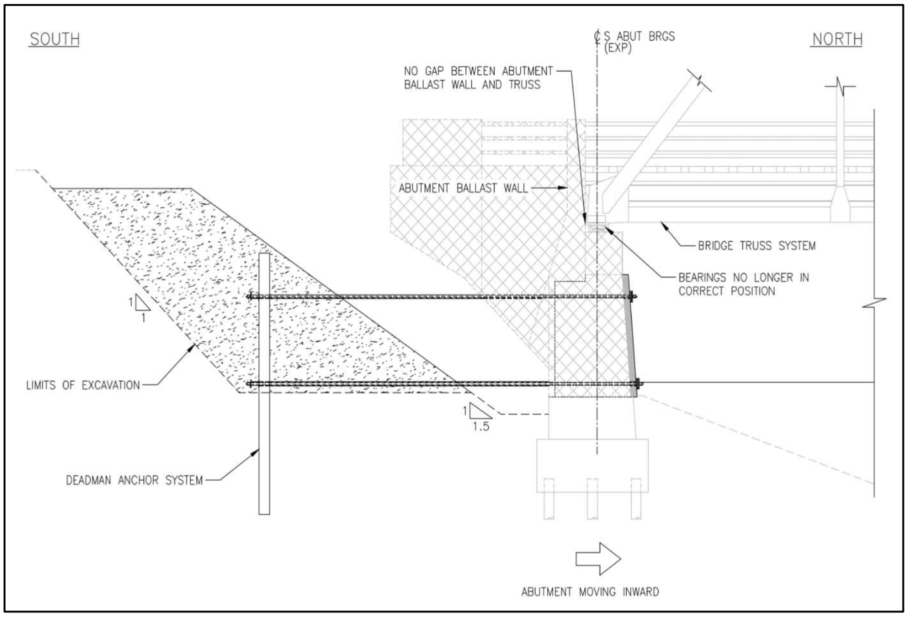
Substructure Repair Scope

- 1 – Dead man anchor system
- 2 - Abutment wall refacing
- 3 - Ballast wall replacement
- 4 - Wingwall replacement
- 6 - Abutment seat reconstruction
- 7 - New south abutment bearings
- 11- New concrete approach slab
- 12 – Sleeper slab expansion joint
- 15 - Embankment erosion protection

To stabilize the abutments from further movement, a dead man anchor system was installed behind the existing abutments. The anchor system, shown in Figure 13, consisted of a sheet pile wall installed behind the abutments.

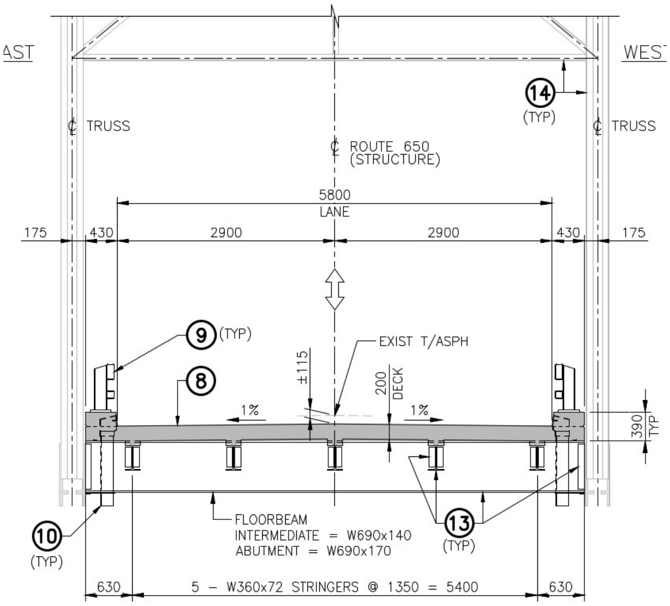
Threaded steel bars were then used to tie the abutment to the sheet piles. The system restrained the abutments from moving forward toward the water.

Figure 13. Illustration of Deadman Anchor System



A summary of the superstructure repairs is provided in Figure 14.

Figure 14. Summary of Superstructure Scope



Superstructure Scope

- New concrete deck
- New metal traffic barrier system
- New deck drains
- Recoating of structural steel
- New approach slabs w/ sleeper slab
- New steel stringers
- New floor beams
- New bottom bracing
- Repair of structural steel including fractured members and rivets
- Embankment erosion protection

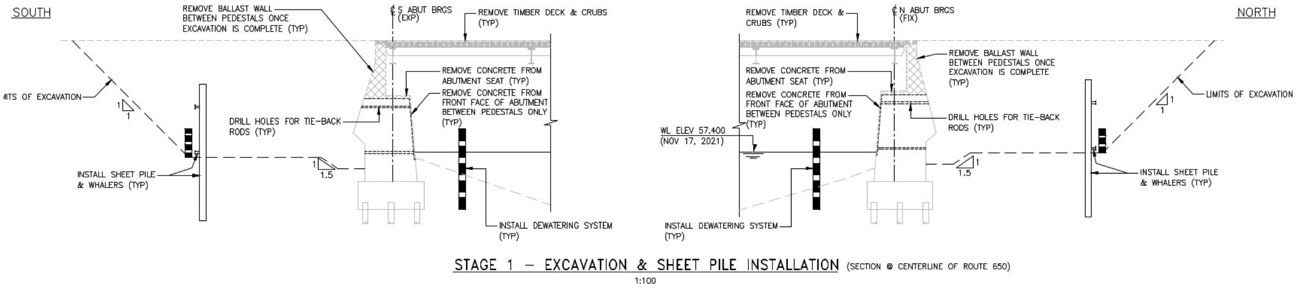
7.0 Sequence of Construction

Based on the results of the analysis, it was expected that the superstructure was restraining the south abutment from rotating further. The position of the superstructure was also being restrained by the north abutment and backfill. Its current condition made it essential that a detailed construction sequence be provided to ensure that the abutments or superstructure did not move.

7.1 Stage 1: Installation of Dead Man Anchor System

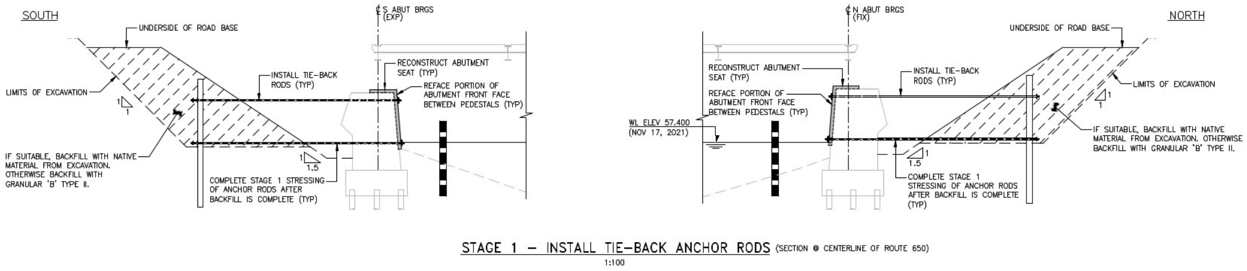
In Stage 1 the Contractor needed to excavate behind the abutments to install the dead man anchor system. Excavation behind both abutments had to be completed simultaneously to ensure the loads remained balance. Once complete, the sheet piles for the dead man anchor were installed and holes were cored through the abutments.

Figure 15. Stage 1 - Excavation



The sheet piles and whalers for the Deadman anchor system were then installed (Figure 15). Once complete, the tie-rods were installed, and the sheet piles were backfilled to permit tensioning of the tie-rods as shown in Figure 16.

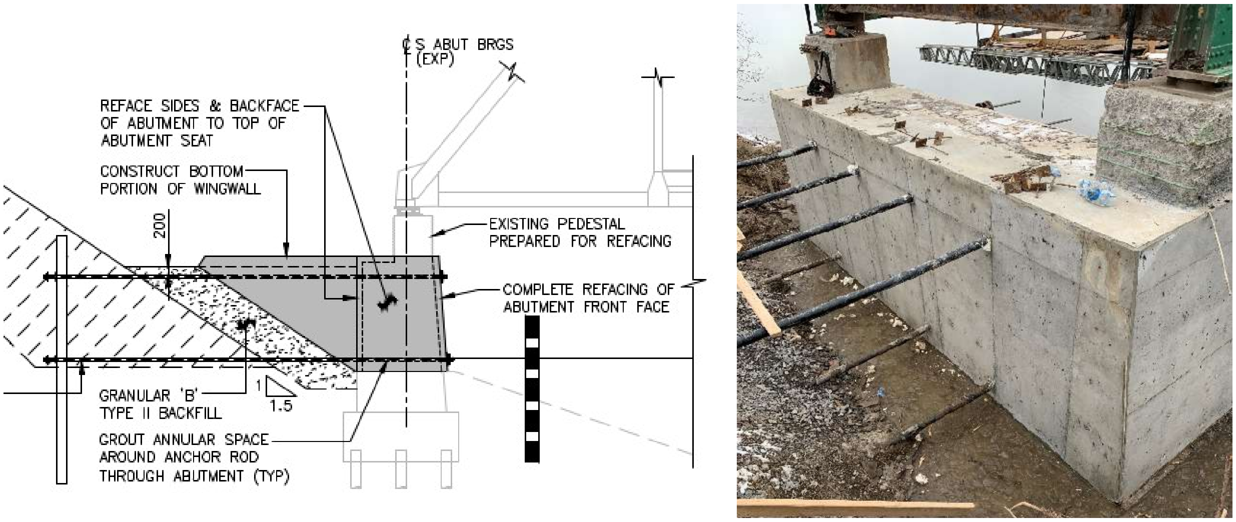
Figure 16. Stage 1 – Tie-Back Install



7.2 Stage 2: Lower Abutment Reconstruction

With the abutment stabilized in stage 1, the Contractor could proceed with the remaining substructure reconstruction. A photo of the reconstructed substructure is included in Figure 17.

Figure 17. Stage 2 – Substructure Reconstruction



Once complete, the Contractor backfilled up to the top of the bearing seat and re-tensioned the tie-rods to restrict any movement caused by elongation of the tie-rods during loading.

7.3 Stage 3: Replacement Abutment Bearings

After reconstructing the lower portion of the substructure, the Contractor proceeded with replacement of the south abutment bearings. The abutment floor beams were used to jack and temporarily support the bridge while work was completed at the bearings. A photo of the bridge on jacks is included in Figure 18.

Figure 18. Stage 3 – South Abutment Bearing Replacement

The bridge was then lowered on to the new bearings and the Contractor then finished reconstructing the upper portion of the wingwalls and ballast walls.

7.4 Stage 4: Deck System Replacement

Following the completion of abutment work, the Contractor commenced the replacement of corroded floor beams and stringers situated between the trusses. To maintain the stability of the truss structure throughout this process, the Contractor adhered to strict guidelines, restricting the replacement to one floor beam at a time. A photo of the replaced floor beams and the new deck reinforcing are provided in Figure 19 and Figure 20.

Figure 19. Stage 4 – Floor beam Replacement

Figure 20. Stage 4 – Deck Reinforcing

With the reinforcing steel installed, the concrete deck pour was completed in a single stage.

With the deck complete, the Contractor just needed to complete construction of the curbs and approach slabs.

8.0 Construction and Schedule

Design and construction followed the conventional Design Bid Build (DBB) model. The Municipality received bids from four qualified Contractors, with proposals ranging from $4.49 million to $5.38 million. In June 2022, Facca Incorporated was awarded the construction contract for $4.49 million.

Undeterred by winter conditions, the Contractor diligently worked through the challenging season and successfully completed the comprehensive rehabilitation project within a remarkable 11-month timeframe.

9.0 Summary

This paper offers a concise overview of how the Egis team effectively stabilized the existing bridge abutments and devised a comprehensive rehabilitation plan to prolong the service life of one of Ontario’s historic bridges.

This project underscored the critical importance of the following principles:

1) **Knowledge**: Engineers tasked with bridge inspections must possess a deep understanding of bridge mechanics and the role of each component. The unnoticed movement of the abutments over decades hastened bridge deterioration, compounded by a jammed deck end hindering the proper functioning of expansion joints.

2) **Analysis**: Early structural analysis can provide invaluable insights into the underlying causes of structural behavior. By modeling the abutments, the team confirmed suspicions of movement without relying on external bridge monitoring systems.

3) **Construction Sequence**: Understanding the sequential order of construction activities is paramount. Identifying a clear sequence in the Drawings prevented potential catastrophic shifts in the superstructure and abutment during excavation by the Contractor.

4) **Construction Experience**: Engaging a skilled Contractor capable of independently executing most of the work, with minimal reliance on subcontractors, proved advantageous. This approach minimized delays and challenges often encountered in construction projects reliant on subcontractor schedules.

These lessons learned underscore the significance of interdisciplinary collaboration, meticulous analysis, and practical experience in ensuring the success of complex bridge rehabilitation projects.

Aerial photos of the concrete deck pour are provided in Figure 21 and Figure 22.

Figure 21. Concrete Deck Pour

Figure 22. Aerial View of Touchette Bridge

References

[1] Canadian Standards Association. *CSA S6:19: Canadian Highway Bridge Design Code*. Mississauga, Ontario (2019)