The Bayswater Covered Bridge Restoration

Background/History

Bayswater Covered Bridge, a two-span Howe truss structure built in 1920, was originally designed to suit the traffic of that era, which was approximately 12 tonnes. Throughout the life of the bridge, degradation has occurred, elements have been replaced, and traffic loads have increased. From a combination of these factors, the structure was down rated from 15 to 5 tonnes in 2019.

Wood Research and Development (WRD) was commissioned to complete a structural inspection and load evaluation of the structure. Non-destructive testing, namely Electronic Pulse Highlight and Outline Diagnostics (EPHOD®), revealed the extent of internal decay of the timber elements and allowed the assessment of their residual capacity.

A structural analysis of the bridge, and a comparison of the results of the demand and resistance, confirmed that the 5 tonne load rating was accurate; however, through the use of advanced timber restoration methods, the structural capacity could be raised to 30 tonnes.

WRD provided New Brunswick Department of Transportation and Infrastructure (NBDTI) with the detailed design of the Bayswater Covered Bridge restoration. The design incorporates various forms of high- strength fibre products to increase shear and tension capacity, as well as use high-grade wood laminations to increase tension and compression capacity.

In addition, some elements required replacement because of corrosion, such as old cast steel connectors and tension rods within the truss. The design intent was to maintain the heritage of the covered bridge while implementing modern technologies to increase the capacity of the existing elements.

1. The bridge in the early stages of repair. New longitudinal glulam decking would be installed to replace the original nail-laminated system.

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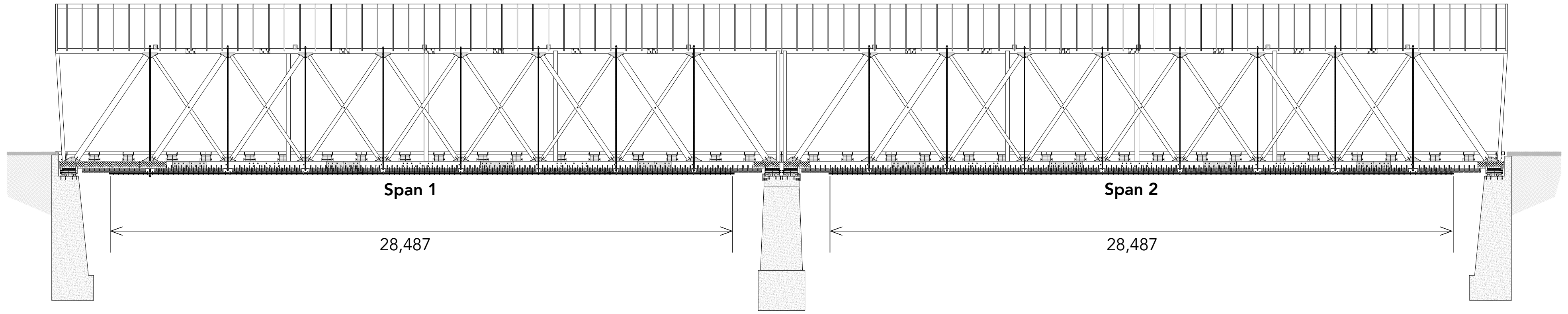
Why was wood chosen

As the original covered bridge was predominately comprised of timber (other than the steel connectors and tension rods), timber was also chosen for the restoration to preserve the heritage of the structure. In addition, the lightweight nature of the material allowed for heavier glulam elements to be used in the deck and floor beams as well as a chip seal wear surface to be installed on a structure that was only intended to carry 12 tonnes. Therefore, in addition to increasing the dead load on the bridge, the design also enabled the increase in live loads.

Precedent for wood bridges that convinced government decision makers

WRD, with expertise in inspection, evaluation and design of timber bridges, was recognized by some NBDTI employees who were taking a WRD course on advanced timber inspection, maintenance and restoration. They were able to see first-hand the capabilities of the reinforcing products. The NBDTI also realized that the cost of replacement and the loss to the community of a heritage structure exceeded the cost of restoration.



Elevation

Design and Construction

The design of the bridge incorporates the original Howe truss superstructure in conjunction with advanced timber restoration methods, with the intent to reestablish and increase element capacity. This is achieved through the following design features:

Tension Chord (Bottom Chord) Repairs

• Using the SWT* data collected during the inspection along with information gathered during the dilapidation survey (an inspection which occurs at the beginning of the construction phase that compares the current level of degradation to the inspection report), the extent of the tension chord repairs were determined. Various layers of high-strength tension reinforcement (Retroten™) were installed on the bottoms of each element to increase tensile and bending strength.

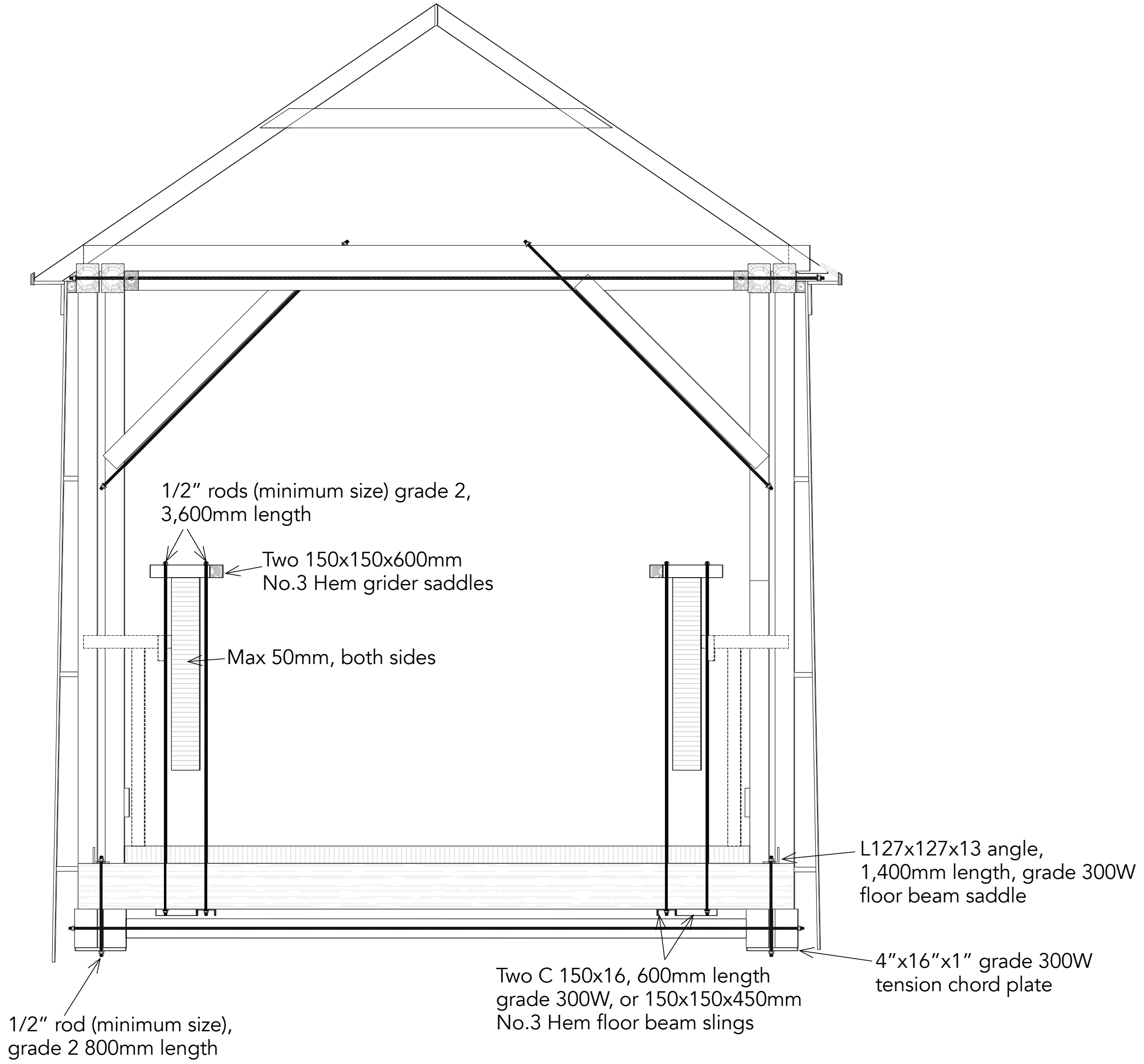
• Shear reinforcement panels (Retroshear™) were also installed along various lengths of the tension chords. Due to the existing floor beam system, both bending and shear forces were introduced into the tension chord. This resulted in some capacity issues which were exacerbated by degradation present; therefore, shear panels were added along various lengths of the tension chord. Shear panels were also installed at tension chord splice connections to increase capacity.

• A few select areas were exhibiting severe decay and loss of section; thus, small portions of the tension chord were removed and replaced with a new timber bevel block. This limited the extent of replacement to only the wood in poor condition.

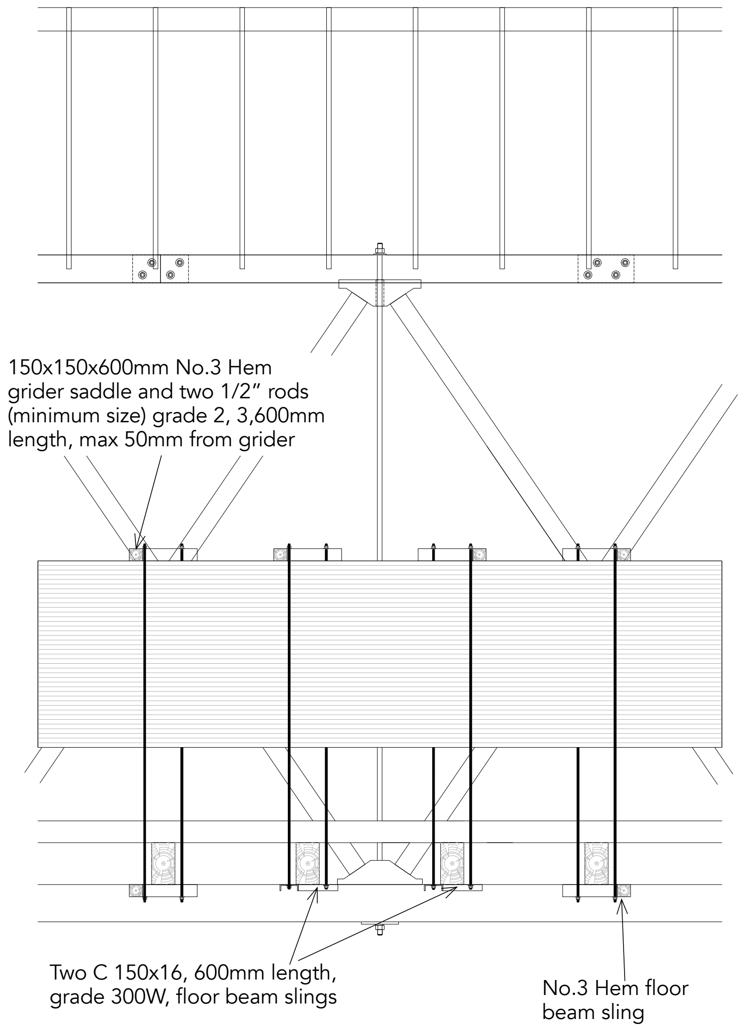
• New floor beams were installed and moved as close to the truss nodes as possible. This limited the amount of bending and shear forces within the chord. However, not all of these forces could be mitigated due to interference with the web elements.

2\. Splice detail of the vertical steel tension rods. See drawing far right.

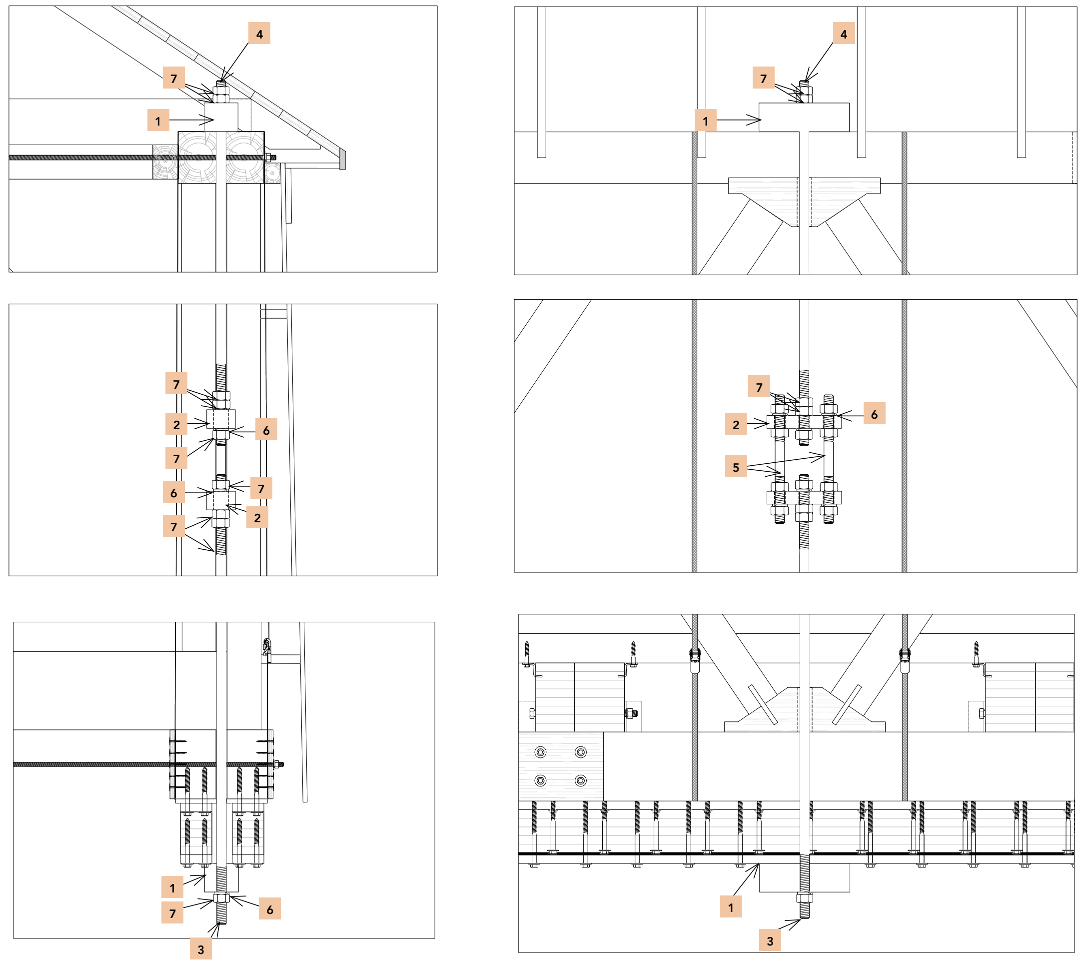
* Stress Wave Timer (SWT) data is collected by measuring the velocity of a "compression" wave through the wood to determine the extent of decay.



Section through a bay during the lifting process



Side elevation during the lifting process



Vertical steel rod connection

1. pl50.8 x 150 x 400 (350w)
2. pl3.25" x 15" x 5" (350w)
3. m57(2-1/4") x 3658mm (12') threaded rod
4. m57(2-1/4") x 2743mm (9') threaded rod
5. m57(2-1/4") x 660mm (26") threaded rod
6. m57(2-1/4") lock washer
7. m57(2-1/4") nut

Compression Chord and Web Elements

• Various compression elements were reinforced using Retrocom products to increase capacity in areas of degradation.

Tension Rods

• All tension rods were replaced with new galvanized elements. Steel considerations for fatigue, torque and fracture control were assessed when sizing and determining steel grade. In addition, due to the roof on the bridge structure, the rods had to be replaced in two halves, requiring a tension splice in the rods.

Other

• New glulam splice blocks were installed in some areas where dilapidation of the connection was noted. This required the temporary support of the bridge section to safely remove these elements.

• Over the years, due to a sag in the bridge, the steel tendon post-tensioning (hawg jaw) system had become engaged. The repairs to the tension chord could not safely occur without the removal of this system. As such, the structure was lifted and supported by two fibre-reinforced glulam beams. Due to the weight restriction on the bridge, the lifting system was largely limited. Luckily, the glulam elements, in conjunction with the high-strength fibre, met this weight requirement. The lift girders were rolled through the bridge on a steel track and put in place one by one. Each span was lifted individually. The bridge was successfully lifted and the load within the hawg jaw was removed. This allowed for the safe removal of the system as well as the reinstatement of camber.

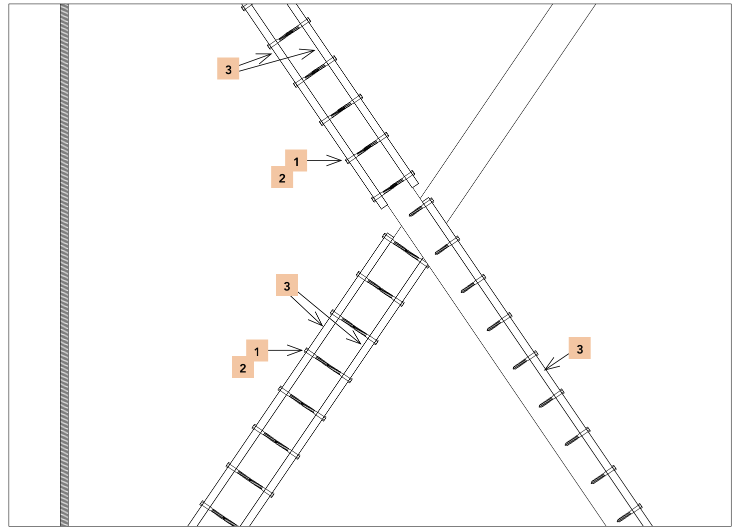
• Vertical connections were removed wherever possible to further extend life.

• New longitudinal glulam decking was installed over the floor beams to replace the original nail-laminated system.

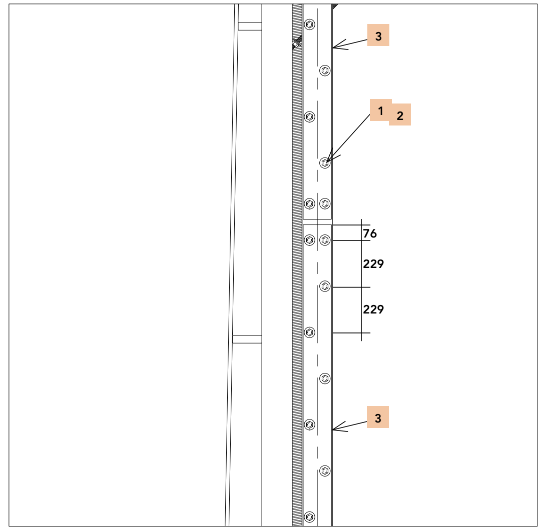
• After construction was complete, a health monitoring system was installed to periodically monitor the structure. The monitoring system was also able to report heavy overloaded trucks traversing the bridge, and can act as an immediate notice to the clients.

3. To support the bridge during construction, two glulam high strength fibre beams were rolled onto each span. The elements were light weight enough to maintain the current bridge posting for installation (5 tonnes), as well as contained sufficient strength to lift the bridge.

4. Compression reinforcement using high-strength timber laminations (Retrocom) were adhered to the web elements and compression chord elements in areas with decay or which required additional load capacity.



Section through Retrocom detail



Plan of Retrocom detail

1. m16 x 130 lag screw
2. m16 plate washer
3. Retrocom

Construction

The construction phase of the restoration was extensive and involved a considerable amount of engineering support. Several underlying structural conditions, which were unable to be detected during the initial inspection, were uncovered during construction. This resulted in a dynamic engineering scenario where engineering and construction were occurring concurrently. Several design changes throughout the construction phase required on-site ingenuity and dexterity due to site limitations. Some of the areas requiring considerable attention include:

- The removal of the existing splice block bolts and timber panels.
- Amputation of the tension chord for the installation of a new timber bevel block.
- The replacement of the hanger rods, with upper and lower bridge conflicts.
- Mitigating winter temperatures and weather, requiring heating and hoarding for applying epoxies.
- The removal of existing elements, and the aversion of in place members. Items for removal included: the existing hanger rods, and the hawg jaw and deck systems.
- General configuration issues from the roof structure above and the embankment slope and beneath.

Several of these items required temporary support during construction, to ensure elements or bolts could be safely removed while the structure remained stable. Many of the elements that underwent high-strength replacement occurred during the bridge lift, where two glulam high strength fibre beams were used to lift the bottom chord, release the tension in the hawg jaw system (allowing for its safe removal) and reinstate camber in the truss.

The Milkish Inlet bridge restoration required substantial skill in both the design and engineering phases. As a team, TRS and WRD accomplished a successful restoration and provided the community with a serviceable bridge that is able to carry up to 30 tonnes. This 100-year-old heritage structure now contains the capacity and design details to continue serving the area for another 50 years or more.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5. The existing floor beams were replaced with new glulam beams and installed as close to the truss nodes as possible. The elements were shifted to reduce bending and shear forces within the tension chord.
6. An overview of the girder lift system, which was designed by WRD, and built by Timber Restoration Services. The lifting system was removed after the Span 2 camber reinstatement and related works were completed. This view showcases the proportions of the lift beams to the current structure.

Corrosion protection of connections

Within the original structure, the primary connection used was wood with some steel fastenings to hold the various blocks together. This strategy was maintained as much as possible. The geographic location of the bridge can cause corrosion and section loss of unprotected steel. Thus, new galvanized bolts replaced the original cast iron bolts while galvanized steel rods, with specialty tightening connections, were used in the restoration. Notch toughness and fatigue were also considerations in the design of the steel hanger system.

Use of Wood

The wood replacement material of Coastal Douglas fir consists of the following:

- The floor beams are 24f-EX glulam
- The deck panels are of grade 16-CE
- The splice blocks are of grade 24F-V4 (AITC)
- Timber laminations consist of No.1 solid sawn material

Select elements within the structure have been treated with copper naphthenate. Since the majority of the structure is protected from the elements via the covered roof, only the first 20 feet of the deck and floor beams are treated against decay. Other items in high moisture areas are also treated, such as at the abutment seats.

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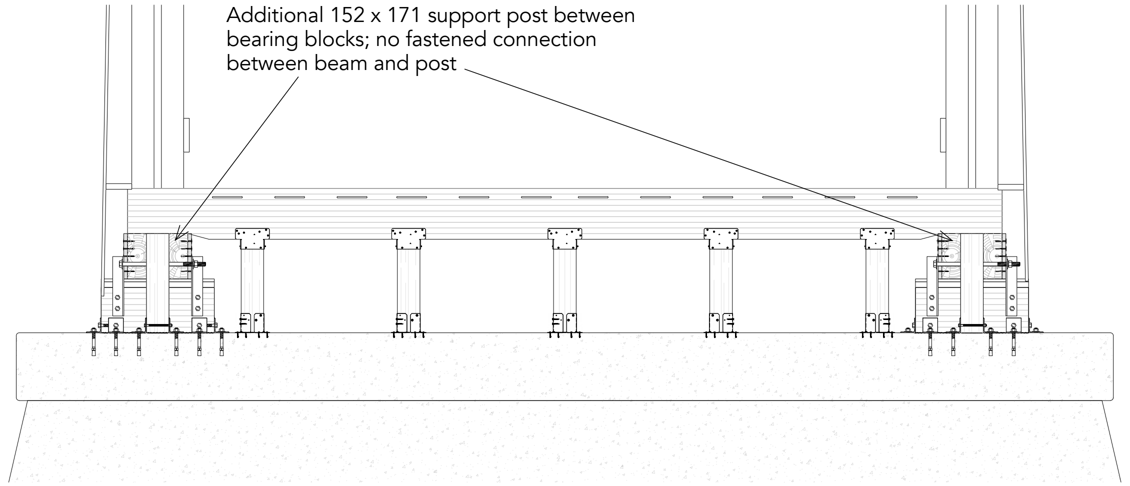
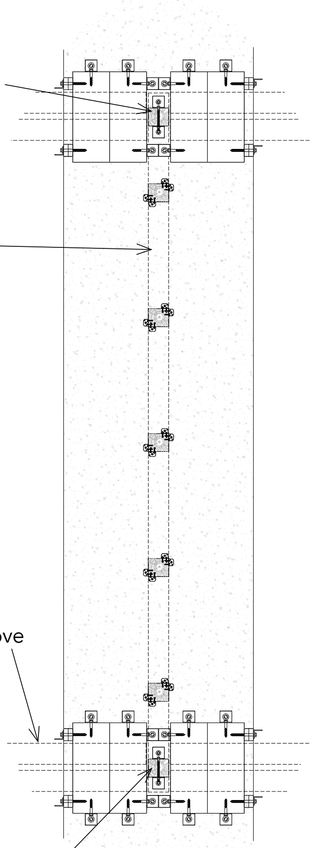
7. The bridge undergoing load testing. As part of the rehabilitation some of the timbers contain borate salt rods which create a brine solution to neutralize pH and prevent decay.



Section at support pier



Plan at support pier

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