BRIDGE SUPERSTRUCTURE REPLACEMENT AT

MILE 50.4 RIVERS SUBDIVISION

CANADIAN NATIONAL RAILWAY

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ABSTRACT

This paper describes the replacement of CN's four-span single-track railway bridge superstructure at mile 50.4 Rivers Subdivision near Portage La Prairie, Manitoba. The original spans, built in 1906, consisted of two 85 ft (26m) through plate girder spans and two 120 ft (36.6m) through truss spans. This structure is a critical link on the CN mainline connecting eastern and western Canada. A slow order was required to operate heavy axle load cars over this structure. To improve operations, CN determined that the spans had to be replaced.

Initial design considerations included building a new structure parallel to the existing and repairing the existing structure, resulting in twin track capacity. Based on economics, CN chose to replace the existing superstructure with four new single-track through plate girder spans.

Three alternative methods of construction were considered:

- launch and slide
- hoisting the spans using conventional cranes on barges
- hoisting the spans using conventional cranes on a temporary dyke

The contractor selected a variation of the launch and slide method. A temporary work bridge was constructed immediately north of the existing structure. During four separate work blocks, CN and VIA Rail traffic was diverted to Canadian Pacific's line. Each old span was jacked and moved on Hillman rollers onto the temporary work bridge and then the new span was slid into position.

The project was completed with no major problems, safely, within the time available and within the $5.6 Million budget.

INTRODUCTION

The Canadian National Railway bridge over the Assiniboine River at mile 50.4 Rivers Subdivision is located in Manitoba approximately 50 miles (80km) west of Winnipeg and 5 miles (8km) east of Portage-La-Prairie.

The old bridge was 411 feet (125m) long and consisted of one approach through plate girder span 85 ft (26m) long at each end and two main through truss spans 120 ft (37m) long over the river. An elevation view of the old and new bridge is shown in Figure 1.

The two through truss spans had a low rating. Strengthening schemes were investigated, but the cost of these was found to be prohibitive. The floor system of the two through plate girder spans also had a low rating. Although replacement of the floor system was possible, replacement of the entire span was not much more expensive, had a significantly longer maintenance-free life and had significantly less impact on railway operations. The concrete piers and abutments were in good condition and could be re-used. It was decided to replace all four spans of this bridge.

Replacement of aging bridge structures on high tonnage, single-track mainlines of heavy freight railways can present difficulties in economics and risk management that may be as challenging as those involved in the "pure" engineering.

The owning railway, the bridge designer, the project manager, the construction manager, the steel fabricator and the contractor must work closely as a team to develop the design and the construction procedure so that not only the up front project cost but also the scheduled interruptions and the risks of unscheduled interruptions to railway traffic are minimized.

Replacement of the superstructure of the CN bridge at Mile 50.4 Rivers Subdivision by rolling the steel spans into position with the aid of a temporary work bridge illustrates this approach and resulted in:

- Reduced risk of delays to railway traffic through the use of multiple short track closures instead of a single long closure.
- Reduced financial risk for the contractor.

DESCRIPTION OF THE SITE

At this location, the topography is flat prairie farmland and the Assiniboine River is shallow and sandy. The track runs approximately 1.5 miles (2.5km) south of the Trans-Canada Highway.

The bridge is accessible by a farm road from the Trans-Canada Highway to a level crossing at Mile 50.54, about a quarter of a mile west of the bridge. The east end of the bridge is also accessible through a farmer's field.

The Rivers Subdivision is double track, primary mainline with bi-directional CTC and carries over 50 million gross tons per year. The bridge is single track and there are dual control switches on each side of the bridge.

The possibility of doubling the track over the Assiniboine River was investigated in an earlier study but was not considered desirable at this time.

The bridge is located downstream of Portage-La-Prairie. Based on historic data, high and low water elevations that could be expected during summer 2001 were established. The fluctuation between high water and low water is close to 6 feet (2m). About two miles (3km) west of Portage la Prairie there is a flood diversion channel that can divert the floodwaters of the river towards Lake Winnipeg. Unfortunately, water elevation cannot be controlled during extreme low water periods.

The fish species in the Assiniboine River spawn in the early spring. It was therefore possible to start work in the river by mid-May to early June. Some erection methods required work to start as early as possible to take advantage of the higher water levels, and others later when the water level had stabilized near its summer level.

The soil stratigraphy consisted approximately of 20 feet (6m) of sand or silt over 80 feet (24m) of clay over till.

PRELIMINARY STUDY

A preliminary study was carried out to establish the possible bridge concepts and construction methods. Although the final construction method would be left to the contractor, it was believed to be important to study the possible alternatives in order to plan well ahead of time for the work blocks and to set aside the funds required to complete the project. Some of the construction alternatives also required special design considerations that had to be identified well in advance, such as the fabrication of the spans which would be nearly completed when the construction contract was awarded.

Alternatives were evaluated using the usual criteria such as cost and impact on railway operations. Some of the other criteria, which were used to evaluate the options, were:

- Effects of natural conditions (water levels, weather, etc.)
- Technical risk (possibility of technical problems leading to exceeding the work block)
- Financial risk (possibility of contractor bidding higher to mitigate risk)
- Compatibility with geotechnical conditions
- Possibility of mitigating environmental impacts
- Maintenance of the navigation channel
- Acceptability by regulatory authorities, adjacent landowners and local government

ALTERNATIVE BRIDGE CONCEPTS

The following alternatives were considered:

- Two spans
- Four spans
- Six spans
- Eight spans

Two-Span Alternative

The two-span alternative would have required spans in the 165 – 200 foot (50-60 m) range, which could only be achieved by Through Truss spans. The fabrication and erection costs of these spans made this alternative uneconomical. Moreover, the existing pier foundations could not have taken the additional loads due to the increased span lengths and costly underpinning work would have been required. This alternative was rejected due to the high costs and the difficulty involved in construction.

Four-Span Alternative

The four-span alternative could be built using the existing substructure elements. Through plate girder spans with ballasted decks could be used to replace both the old through plate girder and through truss spans. Due to the size of the new spans, these had to be shipped knocked-down and assembled on site before erection. The load increase on the foundations was found to be acceptable.

Six And Eight-Span Alternative

The six and eight span alternatives would require construction of additional piers between the existing ones. This would allow the use of shorter spans. Steel Beam Spans with steel ballasted deck could be used. These spans could have arrived on site completely assembled and therefore would not require any field labour for assembly. A comparative estimate was done to see if this alternative would be economical. The comparison showed that the cost of the additional piers exceeded the cost savings for the steel supply and erection. Furthermore, the addition of piers would have restricted the flow of the water and the navigation channel. The alternatives that required additional piers were therefore rejected.

ALTERNATIVE CONSTRUCTION METHODS

The following construction methods were considered:

- Erect with cranes installed on a dyke
- Erect with cranes installed on barges
- Launch spans on falsework and slide sideways in place
- Move spans in and out with barges
- Move spans in and out with trailers on dyke
- Move spans in and out with trailers on ice

It had been previously established in conjunction with CN's Transportation Department that a 72-hour work block could be considered for this project. However, there would be significant benefit if the project could be completed with four smaller work blocks of 18 to 20 hours. This served as a basis for evaluating the different construction alternatives.

Erect With Cranes Installed on Dyke

This method consisted of building a dyke across the river with two bridges in order to allow flow without creating too much backwater.

The spans would be assembled on the dyke using one 250-ton crawler crane. During a work block, the spans would be replaced using two 400-ton crawler cranes. The old spans would be dismantled on the dyke.

Although this erection scheme was based on simple and reliable construction methods, the financial risk for this alternative was significant as the water levels of the Assiniboine River are often difficult to predict.

It had been estimated that the project could be completed in a work block ranging from 48 to 60 hours. The project could also be completed in four shorter separate work blocks if desired. The risk of exceeding the work blocks with this method was found to be relatively low.

Launch Spans On Falsework And Slide Sideways Into Position

This method consisted of installing falsework bents on the north side of the bridge to allow launching the spans across the river. Bents would also be installed at each substructure element to allow sliding the new spans laterally to their final position and the old spans to a location where they could be dismantled. Piles for the bents could be driven using a crane placed either on the riverbank, on a dyke, or on a barge. In this latter case, the required draft for a 40 feet x 60 feet barge was estimated to be 3 feet, which was possible.

The girders would be launched onto the falsework and then braced. The floor system and the remainder of the structural members would then be installed. Once all the spans were assembled, then the old spans would be rolled sideways out of the way and the new spans would be rolled sideways on the falsework to their final position.

The old spans could be dismantled with a crane on the shore, on a barge or on a dyke.

This alternative was found to be economical and had a lesser financial risk for the contractor, as it was not affected by the varying water levels. The risk of exceeding the work block was of concern as a significant number of operations can go wrong during the sliding process.

It was found that the work block requirements for this alternative would be in the 36-48 hour range as more than one span could be moved simultaneously. Moving spans simultaneously however increased the risk of exceeding the work block as there are many operations occurring in parallel, which were part of the critical path for work block completion. The project could also be completed in four shorter work blocks.

Move Spans In And Out With Barges

This method consisted of using barges to move in and out spans No. 2 and 3. Spans No. 1 and 4 would have to be removed and installed using cranes since there may be no water underneath these spans.

Multiple cribs would be built on the shore and in the river in order to provide a dock for the barge, a platform for the crane and temporary support for the spans. The spans would be assembled on the cribs using a 250-ton crawler crane.

During a work block, span No 1 would be replaced with two 250-ton crawler cranes. Once this was done, the cranes would cross over to the other side of the river either using the access roads up to the Trans-Canada Highway or using the barge on site when it was available. Span No 2 would be replaced with the barge using either hydraulic jacks or the water ballast tanks in order to raise and lower the span on and off its supports.

After spans Nos. 1 and 2 were replaced and the cranes crossed the river, the same operations would be repeated for spans Nos. 3 and 4.

After the work block, the old spans could be picked up by the barge, brought close to the shore and dragged onto the shore using a crawler tractor.

This alternative was found to be economical but could only be done at the higher water levels. The financial risk was significant since there is a lot of marine work involved and there was the possibility that there would not be sufficient water.

The work blocks required to do this project was estimated to be 72 hours. The project could also be completed in four shorter work blocks. The risk of problems occurring during the work block was found to be significant.

Erect Spans With Cranes On Barges

This option consisted of using two 400-ton cranes on barges to erect the spans. The required draft, assuming a 60-foot by 90-foot (18m by 27m) barge, was approximately 4 feet (1.2m). This could have been possible at high water levels but not at the lower levels expected through most of the summer and fall.

In addition, only sectional barges could be used at this site. The mobilization of conventional barges was found to be either too complicated or even practically impossible on the shallow Assiniboine River. The use of such heavy cranes on sectional barges is also usually not recommended.

Since the feasibility of this option was questionable it was dropped from consideration.

Move Spans In And Out With Trailers On Dyke

This option is similar to the one which used cranes on a dyke to erect the spans. Rather than using cranes, trailers would be used to haul the spans in and out of position. This option was not found to be economical.

Move Spans In And Out With Trailers On Ice

This option consists of building an ice bridge on the river and then removing and installing the spans with trailers.

There were many drawbacks to this option, which included:

- Lack of control over the weather conditions

- Greater risk of exceeding work block due to winter conditions

There was not much ice on the Assiniboine River during the past winters. Furthermore, due to the shallow depth of water, it may have been technically difficult to build a sufficiently thick ice cover since the flowing water would have continually eroded the bottom of the ice once it had reached a level close to the bottom of the river.

The technical difficulties and the risk associated with this option ruled against it.

BUDGET ESTIMATE

Estimates were prepared for the following alternatives, which were believed to be most desirable:

- Erect with cranes installed on dyke
- Launch spans on falsework and slide sideways in place
- Move spans in and out with barges

The estimates for erection with these three methods varied between $5.0 Million and $5.5 Million. The budget for the project was established at $5.6 Million.

REGULATORY PERMITTING AND APPROVALS

The following regulatory applications were prepared to obtain authorization for the span replacement:

- Application to Canadian Coast Guard in accordance with the Navigable Water Protection Act
- Application to the Department of Fisheries and Ocean for environmental issues
- Notice of Railway Works to adjacent land owners and local government authorities in accordance with the Railway Safety Act

The project was accepted by all parties involved in the project without any objections.

DESIGN

The new spans consisted of through plate girder spans of the same length as the old spans. The spans were designed for Cooper E90 loading with diesel impact. The floor system consisted of rolled sections installed transverse to the main girders. A steel deck plate was installed on top of the floor beams. In order to meet the latest requirements for longitudinal loads, an innovative traction bracing system was designed in order to resist these forces with minimal eccentricity and out of plane movements, which reduce the effectiveness of the traction bracing system. The traction bracing system is shown on Figures 2 and 3.

Mitigative measures were provided in order to minimize the impact on the environment and consisted of:

- Noise was mitigated by limiting construction activities to between 7h00 and 19h00 on weekdays and 8h00 and 19h00 on weekends
- Construction was conducted after the spawning period (spring) to limit the impact on the fisheries resource
- Disturbed ground was restored to the original contours and reseeded
- Temporary roads and direct access to the river not existing prior to construction were restored to original contours and vegetation reseeded
- Refueling and any other mechanical work on equipment were conducted in an area set up away from the river
- Care was taken to prevent material or debris from entering the river
- All scrap metal was recycled.

CONSTRUCTION

A separate contract was tendered and awarded to Canam Structural of Quebec City, Quebec for the fabrication of the steel spans. The span fabrication was carried out from fall 2000 to spring 2001.

The span replacement was tendered for construction in spring 2001. The successful bidder was Louisbourg Construction of Winnipeg, Manitoba. The prices of the fabrication and construction contracts were within the budget established for the project.

The construction method proposed was a variation of the launch and slide method that had been investigated during the preliminary study, with the following exceptions:

- The temporary work bridge would be built with piles supporting continuous cap beams instead of pile bents and spans.
- Pile driving would be progressed from the deck of the work bridge, eliminating the need for barges or dykes.

Site

The main site access was established by road to the east side of the bridge. A work area and span erection pad was provided on the north side of the track.

Temporary Falsework

The centre of the temporary bridge structure was located at 65ft (19.95m) north of the centreline of the existing bridge to clear an existing underground fibre optic cable adjacent to and approximately parallel to the structure.

The temporary bridge consisted of two rows of steel H section friction piles 19’ 4” (5.9m) apart at 5’ 7” (1.7m) centres except at the navigation opening, which provided a clear opening of 10ft (3.05m) for small boat traffic.

Piles at the abutment and pier locations were driven to refusal at 12 blows per inch using a Delmag D-19 diesel hammer. Average penetration was approximately 80ft (24m).

Intermediate piles were driven to an average penetration of 40ft (12m). Longitudinal cap beams were W18 x 41 except for the navigation opening, which had W18 x 55.

The transverse runway beams were WWF 1200 x 364 (48 x 244) connecting to the existing piers and abutments on the south side and WWF 900 x 192 (36 x 129) for the parking bays on the north side.

Connection plates were attached to the abutment and pier noses to support the transverse runway beams. C10 x 15.3 roller guide channels were installed on top of the beams and a 12 inch (0.3m) timber deck was provided for movement of construction equipment and personnel.

Construction proceeded from east to west, initially using one pile driver. Later a second pile driver was added.

An extension of the falsework roller channels was constructed eastward onto the span assembly pad, which consisted of two layers of track ties on rock fill.

Span Assembly and Movement To The Falsework

The steel girders and deck plates for the new spans were transported to the site by rail and off loaded using cranes at the north east side of the existing bridge.

Floor beams and miscellaneous members were transported from the yard in Portage la Prairie by truck to minimize track occupancy.

The spans were assembled in sequence, west span first on the assembly pad and roller channels.

The spans were assembled complete with ballast, track and walkway and were rolled from the east-side assembly area using Hillman Rollers.

They were pulled west along the newly constructed work bridge and then north into the appropriate parking bay opposite their final location.

It was noticed early during the first span movement that the Hillman Rollers worked well on the structural steel falsework but that there was too much deflection on the rock fill assembly platform. This caused the rollers to bind in the channel, requiring the span to be jacked from the rollers and the rollers re-positioned. In some instances the channel was damaged and had to be removed and replaced with a new section. Subsequently a steel plate was welded to the bottom of the roller channels to increase their stiffness and ensure that the rollers would move freely.

Initially a hydraulic puller system was used to move the new spans. This was later supplemented with a D8 crawler tractor equipped with a winch, which was positioned on the west bank.

Span Changeout

Work Blocks

Consultation involving CN, Earth Tech and the contractor developed a plan for 18-hour work blocks to change each of the 86 foot (26m) spans and 22-hour work blocks for the larger 120 foot (36.5m) spans. These blocks were planned for Sunday/Mondays, the period of least train traffic.

Preparation

Prior to the work blocks, all possible preparation work was carried out. This included drilling the new anchor bolt holes and installing a connection between the stringer ends and the truss on the TT spans because these TT spans did not have end floor beams.

Changing TPG Spans

CN track crews removed the rails from the span being replaced but ties were left in place.

Hydraulic jacks were positioned under the floor system, and the span was lifted to allow insertion of a needle runway beam and rollers.

Hydraulic pullers and cables were connected and the span was pulled to the north to line up with the east-west runway.

The span was then jacked, the rollers were turned and the span was pulled clear to the east or west.

While the old span was being moved, the final anchor bolt holes were cored and the abutment backwall was saw cut to adapt to the new ballasted deck span from its former open deck configuration.

Hydraulic pullers and cables were designed to fasten to the south side of each abutment and pier, the cables were connected to the new TPG span and the span was pulled into position.

CN track crews re-connected the track, did a final track surfacing and the bridge was re-opened for train traffic.

Changing TT Spans

One extra operation was required in changing the through truss spans because they were narrower than the TPGs.

They required a carrier beam to be installed under each end so that rollers could be placed at wider centres than the trusses to match the “track gauge” of the east-west runway and resulted in having to jack the TT spans about a foot higher than had been necessary for the TPGs.

Cleanup And Site Restoration

The old spans were dismantled, cut up and removed from the site by truck.

The temporary falsework was dismantled and all piles were pulled using a vibratory puller.

Rip rap was placed along the east and west shores and around the piers and abutments, both for erosion protection of disturbed soil and as a mitigation measure to provide fish spawning habitat.

The disturbed ground surface was restored to the original profile and in the spring of 2002 it was seeded with appropriate vegetation.

CONCLUSIONS

- Superstructure replacement cost was $13,600 Canadian ($8,600 U.S.) per foot.
- The most economical replacement method was rolling steel spans using the work bridge construction method at this location. Even though it required more construction infrastructure, planning and detailing, it reduced the contractors' financial risk. For example, when using a method requiring large cranes, if he missed a scheduled track closure or had equipment problems with a 400-ton crane and needed a replacement, on a project of this size, the extra costs could easily exceed any reasonable contingency expectation and the tender price would have to reflect this possibility.
- Construction staging using short track closures (2 - 18 hour & 2 - 22 hours versus 1 - 72hour) is beneficial because it limits the risk to the railway of a unplanned extension to the track outage if something goes wrong during the work block and allows for a "learning curve" effect for the contractor who becomes more efficient with each work block.
- Hillman rollers are a very effective means of moving heavy spans but the guide channels need to be fully supported with a smooth, level, straight and unyielding base. If the base is flexible or undulating (e.g. slight differences in a transversely oriented timber floor), then the rollers will likely crimp the steel channel web and become wedged.

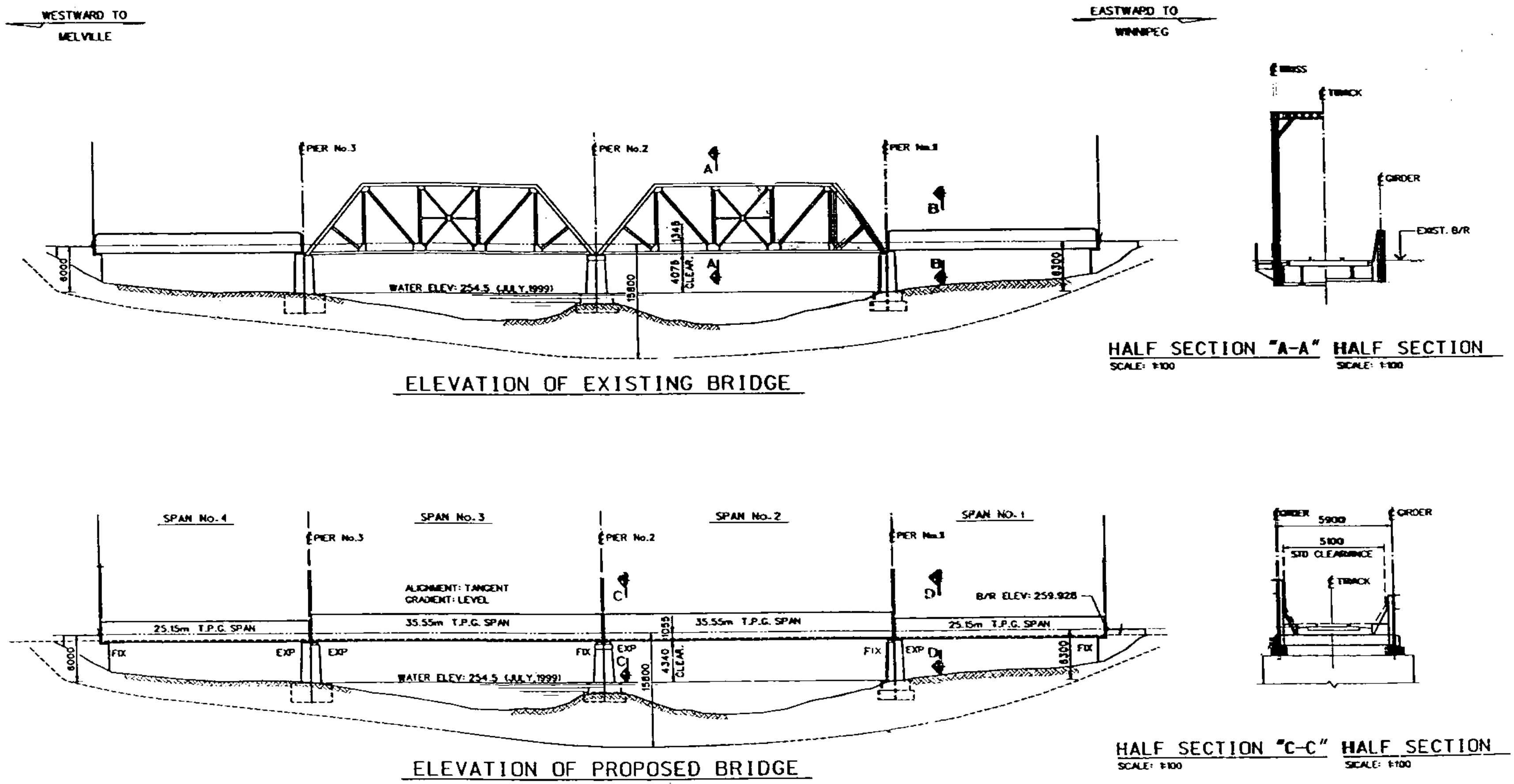

Figure 1. Bridge Elevations

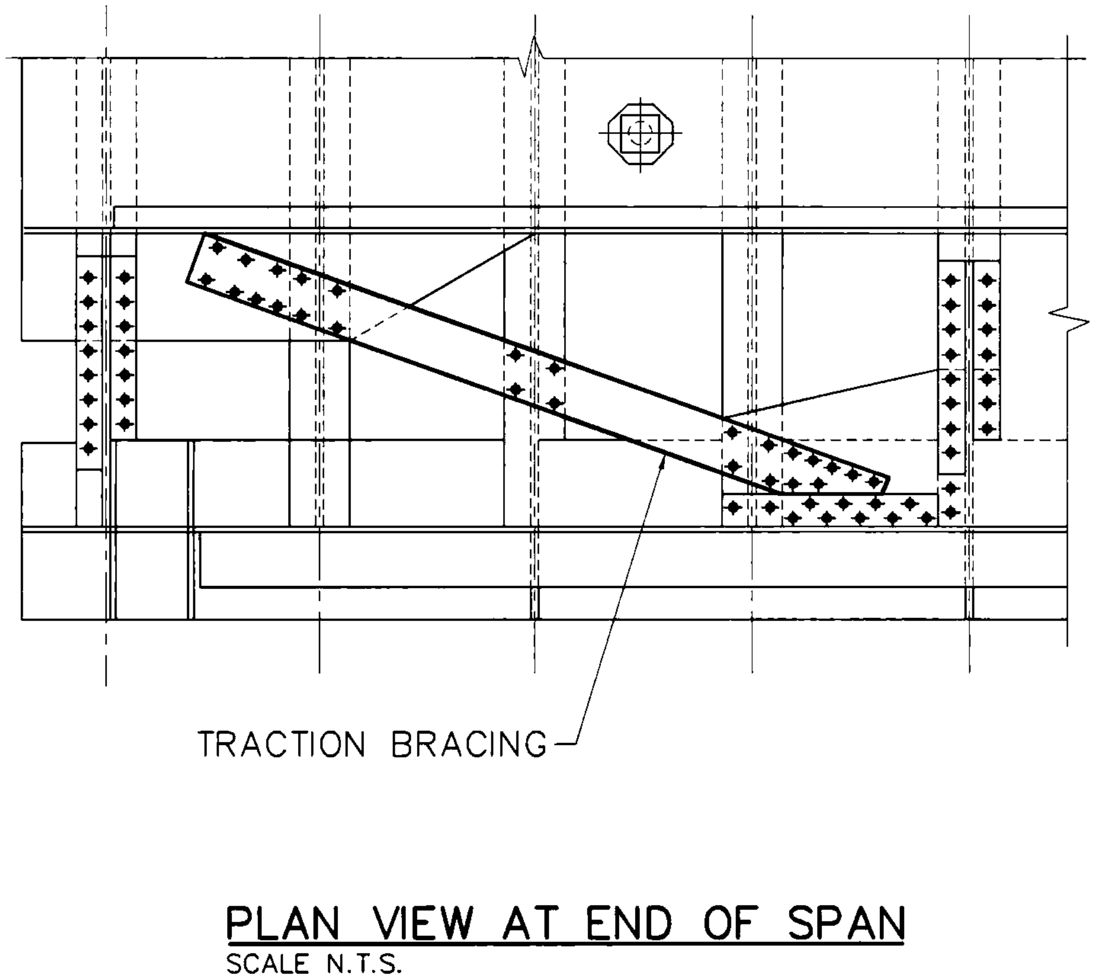

Figure 2. Traction Bracing – Span Ends

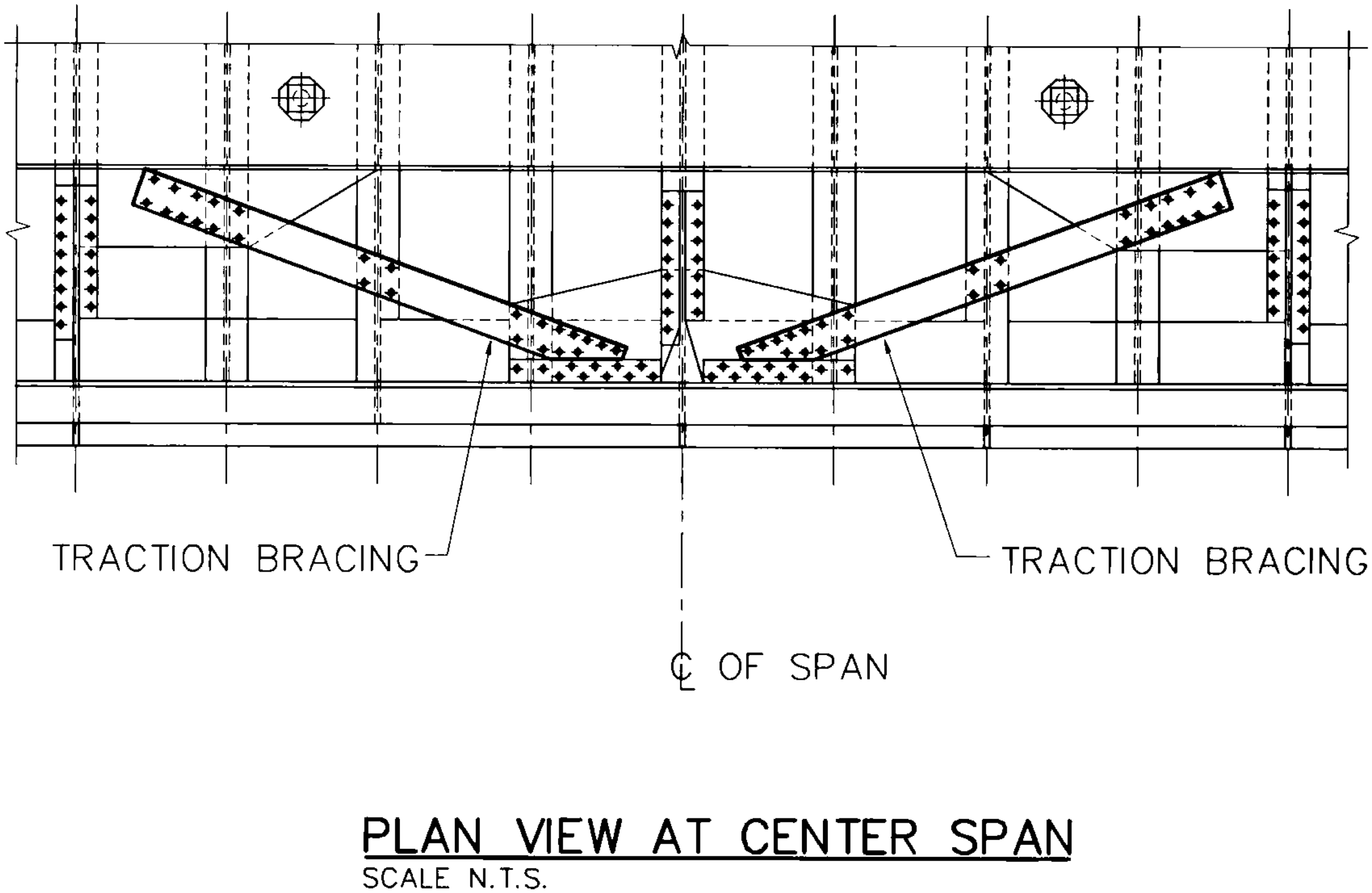

Figure 3. Traction Bracing – Mid Span

Photograph 1

Rolling out through truss span

Photograph 2

New spans and work bridge

Photograph 3

Completed structure