BNSF Railway Bridge 294.1 Replacement – Winter Construction Window in Ponca City, Oklahoma

Principal Author
James P. Hyland, PE
Senior Bridge Engineer
TranSystems
2400 Pershing Road, Suite 400
Kansas City, MO 64108
816-329-8735
Jphyland@transystems.com

Doug Kolb
Vice President
OCCI, Inc.
3200 County Road 257
Fulton, MO 65251
573-642-6087
DougK@occimofab.com

Number of Words in Text = 4079
Number of Figures & Photos = 10 Total
Number of Words = 6579

ABSTRACT

The existing BNSF Bridge 294.1 consisted of two 48” deck plate girder spans and three 124’ through truss spans and was being replaced with an in-line replacement bridge consisting of two 39’ double cell concrete spans, two 62’ deck plate girder spans and three 127’ through plate girder spans supported by CIP or precast concrete caps and drilled shafts.

The construction plan for the in-line replacement of this bridge occurred during a specified track window that included placement of a causeway across the Salt Fork River originally set for October. OCCI chose to use Self Propelled Modular Transport’s (SPMT) for both the removal and replacement of the bridge components. The existing truss spans were lifted by crane and placed on the waiting SPMT, then transported to the staging area one at a time where they were removed and replaced by the new TPG spans that were then transported back to the bridge and lifted into place by the cranes. With scheduling changes, the track window ended up occurring the weekend of January 4, 2014. The winter climate brought its own challenge, with a 24 hour wind delay where the temperature dropped from 40 degrees to 0 with winds over 30 mph in which the cranes could not safely lift the loads. TranSystems, the OCCI and BNSF worked together to find multiple alternatives to replace the remaining spans to get the bridge back in service if these conditions continued. As a successful result of these efforts, trains were placed on the new bridge by 6 am Monday morning.

INTRODUCTION

Located five miles south of Ponca City, Oklahoma, a 480-ft. single-track bridge over the Salt Fork of the Arkansas River has passed the test of time by safely providing main line rail service for over 115 years. Originally constructed in 1899, the BNSF owned and operated bridge is located at MP 294.1, Line Segment 7400 on the Red Rock Subdivision between Ponca City (MP 288.9) and Marland, Oklahoma. Over the life of the structure, significant rip-rap and grouting around the piers was performed to help mitigate scour and substructure displacement issues in order to prolong the lifespan of the bridge. The span configuration of the 480-ft. bridge consists of a 48-ft. deck plate girder (DPG) approach span, three 124-ft. through truss spans, and a 48-ft. DPG approach span. The spans were supported on timber...
pile deep foundations supporting masonry piers. An average of 20 trains per day operate over the bridge with a timetable track speed through this location of 55 miles per hour (mph). Due to the condition of the existing structure, a 25 mph slow order was placed on the structure. Traversing ten states and having moved nearly 200 million tons of freight in 2009 (reference BNSF Analysis for Alignment Alternatives and Hydraulic-Hydrology for the Replacement of Bridge 7400-294.1, over Salt Fork of the Arkansas River near Ponca City, Oklahoma FINAL REPORT), this connection is vital to BNSF’s MidCon route from Texas to Canada.

The condition of the existing bridge has deteriorated over the last 115 years of operation as one would expect. The bearings and steel diagonal truss braces alone have required repair resulting from pier scour and movement. In 1951, another structural retrofit converted the bridge from an open deck bridge to a ballasted deck bridge. Scour around the bridge foundations continued to directly impact the integrity of the structure and approach embankments requiring continual maintenance and repair.

Consequently, in 2011, the BNSF Railway authorized an engineering evaluation to analyze alignment alternatives along with hydraulic/hydrology of the Salt Fork of the Arkansas River. The analysis was limited to placement of the new bridge on the existing alignment with similar spans lengths and structure depths to minimize approach embankment work. Based on this report, the BNSF Railway authorized TranSystems to begin the engineering design of the in-line replacement of the single track bridge. Unlike the original alignment study, the final design required track raise of the bridge to meet hydraulic criteria. The new bridge consists of a single-track, 7-span, 586-ft. bridge including three 127-ft. main span through plate girder spans, two 62-ft. steel deck plate girder spans and two prestressed concrete double cell box beam spans. The general elevation of the bridge is shown in Figure 1 and the through plate girder and deck plate girder spans are shown in Figure 2.

The north abutment was placed north of the existing abutment within the existing embankment to better align the new bridge spans with the existing channel. Under the north spans of the existing bridge and just upstream of the bridge, significant rip-rap had been placed over the years to protect the existing abutment. The existing north embankment was removed during the in-line bridge replacement track window. The south abutment was placed just north of the existing abutment to better align the new bridge with the existing channel.
Figure 1 – General Bridge Elevation
Along with the replacement of Bridge 294.1, the hydraulic analysis determined that significant rip-rap was warranted at Bridge 295.1. Rip-rap and erosion blankets were placed at Bridge 295.1 prior to completion of Bridge 294.1.
DESIGN CONCEPTS

As an in-line replacement, the design of the new bridge required coordination of the new substructure with the existing substructure piers and abutments. The placement of the substructure for the new bridge consisted of two abutments and six piers. The north abutment and north two piers were constructed within the existing embankment north of the existing abutment. The remaining piers and south abutment were constructed between the existing piers and south abutment. The four south piers were designed utilizing drilled shafts placed outside the existing truss clearance with cast-in-place concrete columns supporting a cast-in-place concrete pier cap. The top of the pier cap was placed with a minimum of 1’ clearance below the existing low chord of the trusses. See Figure 3 for typical section of the cast-in-place concrete pier.

Figure 3 – Cast-in-Place Concrete Pier

The layout of these piers allows for the drilled shafts to be installed without disrupting train traffic constructed prior to the track closure window. The columns were constructed on top of the drilled shafts without disturbing the existing bridge or train traffic. Additionally, the pier caps were constructed under the existing low chord prior to the track window. With the pier caps constructed under the existing low chord and the top of rail was being raised, precast concrete steps were required on top of
the pier caps. These precast concrete steps could not be installed prior to the track window since they interfere with the existing bridge superstructure; therefore they were required to be a step in the construction process during the track closure window, which are shown in Figure 3.

The south abutment was located north of the existing south abutment within the south approach deck plate girder span. The south abutment was supported on driven h-piles and is a precast concrete abutment. Since the existing south approach span has a timber deck supporting the ballasted deck and the depth was limited under the approach span, the steel h-piles were constructed from above the deck. During a small track window, the new piles were located on the existing structure and the timber deck was opened up and shored to maintain the ballast section around the new pile locations. Additionally, the lateral bracing and diaphragms were modified to allow the piles to be driven around the existing deck plate girder span. Once these two steps were complete, a final small track window was utilized to drive the abutment piles and cut them off below the top of the deck. After the pile cutoff, the track window was released.

For the north abutment, the construction was more difficult since it was located within the existing embankment. The north abutment was also supported on h-piles and a precast concrete abutment. Similar to the south abutment piles, the h-piles were driven around the existing track during a small track window. Once the piles were driven, they were cutoff below the top of existing rail.

However, the two north piers could not be designed utilizing h-pile supports due to the proposed span lengths and required capacity. The two piers utilized drilled shafts that were placed outside of the track similar to the other piers supporting a concrete pier cap. Since these two piers are located within the embankment section, there were a few methods of construction. First, temporary shoring could be placed on either side of the pier cap and a jump span placed over the gap between the temporary shoring. This would allow the pier cap to be cast in place but would require more track windows during the construction. This first method was not utilized. A second method was to have the drilled shafts already constructed prior to the track window and construct the pier cap during the main track window. While this was an option, the amount of time required to cast two of these piers was deemed too long for the track closure window. A final method involved precasting the pier cap and connecting it to the drilled shafts utilizing a special designed connection. The special connection includes a steel beam that is anchored in the top of the drilled shafts and then the precast concrete cap has pockets placed in it to allow the steel beams to be grouted into the precast cap (see Figure 4). This method required temporary shoring between the shafts and the track to allow construction of the special connection to the precast pier cap due to the depth of the cap and close proximity to the existing track.
Figure 4 – Precast Concrete Pier Cap

Based on the location of the drilled shafts and proposed span lengths, the width, depth and lengths of these precast concrete pier caps were larger than any normal precast cap. While they could be precast at a precaster, the design also allowed them to be constructed on site to eliminate shipping to the site.

The use of precast concrete pier caps of these sizes was unusual and provided challenges with the design and detailing. The main challenges dealt with the placement of the main reinforcing steel around the pockets in the precast caps and the design of the steel connecting beams. The main reinforcing steel both in the top and bottom had to be placed in multiple layers adjacent to the pocket. The shear reinforcing steel also had to be placed around the pocket. The design of the steel connection beam included placement of shear studs on the beam to transfer the moment from the pier cap ends to the drilled shafts. The beam was designed to transfer the total moment across the joint between the precast pier cap and the drilled shafts.

While the design was unique, the construction of the connection beam in the drilled shafts required the connection beam be accurately placed into the top of the drilled shaft and be held in place during the curing of the drilled shaft. A frame was connected to the top of the drilled shaft casing to hold the steel connection beam in place during concrete placement. Once the concrete cured, the connection beam was surveyed again to verify the proper placement of the connection beams for placement in the precast pier cap pockets.

The grout that was designed for filling the precast concrete pier cap pockets was based on the amount of time allotted for the pier cap construction during the track closure window. A high early grout was required and specified to allow placement of the superstructure spans on the pier cap within 12 to 24 hours.

CONSTRUCTION

© AREMA 2015
The new substructure is constructed of drilled shafts with cast in place concrete columns and caps beneath the existing structure. OCCI self-performed this work with the exception of the pre-tying of the reinforcing steel cages. The drilled shafts are permanently cased, and were installed utilizing a track mounted drill through both the overburden and the rock socket. Following excavation of the shaft, the hole was inspected utilizing an underwater camera, and immediately following any necessary cleaning, the rebar and concrete were placed.

Conventional construction methods were utilized to construct the cast in place concrete for the columns and caps. The caps were mass concrete, and the proper cooling tubes and temperature monitoring was performed.

The first two intermediate bents on the north end of the new bridge were north of the existing abutment. As such, the shafts were drilled through the existing embankment, and precast caps were constructed that would then be placed on the shafts during the track closure. OCCI constructed the precast concrete pier caps on site. They weighed approximately 100 tons each, and were constructed in a location which could be picked and swung into place with a conventional crawler crane.

The Through Plate Girder spans were assembled on site in the staging area on cribbing such that the SPMT units could drive directly beneath them. The spans consisted of floor beam panels from the fabrication shop which already had the ballast plate attached. OCCI performed the assembly of the steel then welded the ballast plate seams and curb plates. Photo 1 below shows an overall site view.

![Photo 1 – Overall Site View Including Staging Area](image)

The two 62’ Deck Plate Girder spans were located one each on the north and south ends of the bridge and were assembled in a location such that they could easily be picked and swung into position during the track outage. Again, the assembly including the welding of the ballast plate was performed with OCCI’s own forces.

The two intermediate bents on the north end of the project were constructed north of the existing embankment due to the proximity to the center of the rail, and the elevation of the top of shaft:

1. 5 Ft diameter drilled shaft
2. 14 Ft from the centerline of rail to the centerline of shaft.
3. 11 Ft from the top of rail to the top of the drilled shaft.

The top of the drilled shaft had a connection beam cast into it that would be the connection to the precast cap and needed to be located accurately so that there would not be problems with the fit of the cap during the track outage. As you can imagine, it took significant shoring to install these four drilled shafts. OCCI designed and constructed sheet pile shoring along either side of the rail approximately 90 feet long to include an area to construct all four shafts and have access for the drill and other construction equipment. See Photo 2 for shoring and connection beam frame.
As previously mentioned, the new Through Plate Girder (TPG) spans were constructed in the staging area. The permit for the project allowed for a causeway to be constructed across the full width of the Salt Fork of the Arkansas River. OCCI's approach was to then locate two large cranes (One 400 ton and one 300 ton) on the causeway to pick both the existing trusses and the new TPG spans. The cranes picked and set an existing truss on the Self Propelled Modular Transport (SPMT) unit which then transported the span to the staging area and set it on cribbing which is shown in Photos 3 and 4.
Photo 3 – Causeway and Test Pick of TPG Span from SPMT with Cranes
This process was repeated for each of the three existing spans, as there were precast pedestals that had to be anchored to the new bent caps in order to get the proper elevation of the new spans.

Following the precast pedestal installation, the SPMT unit then transported the TPG spans to the causeway for erection by the cranes. The SPMT units have enough lift motion that they were able to lift the spans off of the cribbing, and as such the large cranes could stay on the causeway, and not have to track back and forth between the staging area and the causeway.

An additional 300 ton crane was located on the north end of the bridge to erect the precast (100 tons each), the 62 ft DPG span, and service the various construction on that end of the bridge as it was significantly higher in elevation that the causeway, and could not be reached by the cranes there.

OCCI had 37 hours to perform the removal and replacement of the structure including initial placement of the ballast and track panels during the track outage followed by 11 hours for BNSF crews to finish the track installation. In order to pull this off, extensive preplanning is necessary. This preplanning included the following:

1. Hour by hour schedule – OCCI utilizes Primavera’s P6 enterprise CPM scheduling software to plan not only the entire projects, but we also to build an hour by hour schedule for the time critical operations with complete resource loading.
2. Weekly closure coordination meetings in addition to our normal weekly project coordination meetings were help starting several months prior to the closure with all parties involved.
3. Extensive contingency plans – Plan for the worst – hope for the best:
   i. Contingency Plans for crane breakdown
   ii. Multiple High Performance Concrete Mixes – the concrete that connected the precast
concrete caps to the drilled shafts on the north end needed strength in hours – not days. OCCI not only designed both at pre-bagged mix and a ready mix, multiple test batches of each were completed to ensure that we had a method that would work.

4. OCCI does not expect our crews or management staff on site to work excessive shifts, and as such, our crews are split into 12 hour shifts, and a management handoff meeting is held at the beginning of every shift to achieve a smooth transition. This ensures that every team member gets adequate rest and is alert to make both safe and quality decisions.

Mother Nature – unfortunately, with all the best laid plans, Mother Nature still had to prove she was the boss (See Photo 5). OCCI closed the bridge to rail traffic around 5pm on Friday evening January the 5th 2014. Up until that point the weather had been ideal for that time of year, with temperatures in the 50s and sunny on Saturday afternoon. However, at approximately 5 pm on Saturday the weather changed drastically.

Photo 5 – Wind and Snow Prove to be Challenging Adversaries

Temperatures dropped to below freezing, and we experienced high winds with gusts over 30 mph – beyond the design capacity for the crawler cranes.

Even though we were not able to control the winds, and following a 25 hour delay due to the weather, we were able to turn the bridge back over to BNSF around 6am Monday morning – only 14 hours after the original deadline and run the first train. Fortunately, we were able to communicate this to BNSF early enough, and they were able to communicate it to their transportation department and minimize the impact.
TRANSPORTATION COORDINATION

The BNSF planning for the track closure window began as the project construction was started. The length of the track closure window had already been set during design, but was confirmed with OCCI and BNSF transportation department. With 48 hour track closure window, a more detailed schedule was developed by OCCI to include removal of the existing track from the existing bridge and the placement of the new track on the new bridge. Since BNSF forces were completing those tasks, that time was removed from the construction time allotted to OCCI for bridge removal and replacement.

While BNSF transportation department agreed with the 48 hour track closure window, the determination of the best time of the year to have the track closure window was reviewed by BNSF. At the beginning of the project construction, the track closure window was tentatively set for October. As the project construction progressed, it was determined that moving the track closure window later in the year was necessary and was requested from BNSF transportation department. With the increase in train traffic during the late fall until Christmas, the track closure window was not allowed until after January 1st, 2014.

The revised track closure window was set to begin at 5 pm on January 4th, 2014 and end at 5 pm on January 6th, 2014. An alternate date was also assigned for the following weekend if weather was deemed to be prohibitive. With these dates set, the planning between BNSF, TranSystems and OCCI, began in August with a kickoff meeting to discuss OCCI’s detailed construction schedule. Additional meetings progressed each month with more details and inclusion of other BNSF representatives. Finally within November and December, the meetings became part of the weekly progress meetings.

As the track closure window was getting closer, the discussion of the actual OCCI detail construction plan had been developed enough detail that the discussion turned to contingency planning aspects of the track closure window plan. This included what additional items OCCI was required to have on site. These discussions included more and more people as the track closure window got closer. The final two weeks before the track closure window, daily meetings were held to confirm placement of the
contingency items and status of weather updates for the track closure window weekend. With the final
days before the track closure window, and the status was a go for the track closure window, BNSF
transportation began to reroute trains around the bridge. With the final weather forecast, a final go was
given on the January 3rd meeting.

On January 4th, 2014 at 5 pm the last train passed and the track closure window began. With the
window beginning, communication with BNSF transportation in the form of status updates was sent
every 6 hours. As the weather temperature dropped and the wind gusts exceeded 30 mph around 4
pm on Saturday January 4th, the communication with BNSF Transportation was increased and added
pressure to finish the construction within the allotted track closure window so trains were not delayed
more than expected. The winds gusting over 30 mph exceeded the allowable wind speed for crane lifts
so the construction was on hold until the winds receded below 30 mph. While construction was on
hold, the on-site team brainstormed ideas to get the bridge in service if the winds did not cooperate.
Therefore, the communication with BNSF Transportation became even more critical if construction was
going to exceed the track closure window since BNSF had begun placement of trains at either end in
preparation for the release of the track back to them.

The wind gusts did finally subside after about 25 hours of delay and the last spans were set late on
January 6th and the track was returned to BNSF transportation around 6 am on January 7th.

CONCLUSION

While the completion of a track closure window in January added complication to the in-line replacement
of the bridge, coordination and communication aided the successful completion of this bridge
replacement. Even with all the planning, Mother Nature can still pose challenges beyond those predicted
by any weather forecast. The team rose to the challenge and limited the extension of the track closure
window to 14 hours beyond that required despite the wind gust delay of 25 hours.

LIST OF FIGURES

Figure 1 – General Bridge Elevation
Figure 2 – Typical Section of Deck Plate Girder and Through Plate Girder Spans
Figure 3 – Cast-in-Place Concrete Pier
Figure 4 – Precast Concrete Pier Cap

LIST OF PHOTOS

Photo 1 – Overall Site View Including Staging Area
Photo 2 – Temporary Shoring and Connection Beam Casting Frame
Photo 3 – Causeway and Test Pick of TPG Span from SPMT with Cranes
Photo 4 – Staging area with TPG and SPMT
Photo 5 – Wind and Snow Prove to be Challenging Adversaries
Photo 6 – First Train over the New Structure
BNSF Railway Bridge 294.1 Replacement – Winter Construction Window in Ponca City, Oklahoma

JAMES P. HYLAND, PE
DOUG KOLB, PE
Existing Bridge

Site Map

Bridge Replacement
- 115 Years Old
- History of Scour Issues
  - Pier Scour
  - North Abutment
- Heavy Debris
- Channel Migration
- Slow Order – Bridge
- Increased Rail Traffic

Proposed Bridge
- Shifted Bridge North – Better Channel Alignment
- Lengthened Bridge – Original 480’, New 586’

Bridge Design
- In-line Replacement
  - Substructure Construction
    - Around existing bridge substructure and superstructure
    - Within existing embankment
    - Through existing bridge
  - Track Window – Bridge Replacement
    - 48 hours

Bridge Design
- Superstructure Construction
  - Causeway – Allowed by permit
  - Options for removal of existing trusses
  - Options for placement of new TPG’s
Bridge Design

• Pier Design
  – Drilled shafts supporting CIP Concrete Cap placed under existing superstructure
  – Drilled shafts supporting Precast Concrete Cap with steel beam connections

• Abutment Design
  – H-piles
  – South abutment piles driven through existing bridge deck

Construction

• Causeway Installation
  – Installed portion from each bank to allow access to drilled shafts in the river
  – Channel remained open for the majority of the construction season
  – Installed pipes and closed gap in causeway for span change-out
Construction

Causeway Phase 2

Construction

OCCI self–performed construction of Precast Concrete Caps on-site

Construction

OCCI self-performed drilled shafts

Construction

Through Plate Girder Span & Deck Plate Girder Span assembly

Construction

• Shoring at bents 2 & 3 for drilled shaft installation
  – 5 FT diameter drilled shaft
  – 14 FT from center line of rail to center line of drilled shaft
  – Top of drilled shaft approximately 11 FT below top-of-rail

Construction

Shoring at bents 2 & 3 for drilled shaft installation
Construction

• Pre-Planning
  – Hour by hour schedule
  – Weekly meetings specific to the change out started months in advance

Construction

• Pre-Planning - Contingencies
  – In case of crane breakdown
  – Multiple high-performance concrete mixes
  – Crews started days in advance practicing actual closure work methods

Construction

• Pre-Planning
  – Split management in 12-hour shifts and had management coordination at each shift change

Construction: Span Change-Out

Pre-assembled steel in lay-down yard

Construction: Span Change-Out

Pre-assembled steel in lay-down yard

Utilized SPMTs to transport spans to/from causeway
**Construction: Span Change-Out**

Planned: 37 hours

*24 hours in –*

Weather changed from 50° & sun to 30° with 30+mph winds

---

**Construction: Span Change-Out**

*25 Hour Weather Delay*

Completed only 11 hours past schedule

---

**Construction: Span Change-Out**

End of Weather Delay

Setting Spans Again!

---

**BNSF Transportation Coordination**

- 48 hour track window
- Set date for window
  - Original Fall 2013
- Multiple detailed schedule review meetings
  - Increased as track window approached
- Rerouting of trains – track window

---

**BNSF Transportation Coordination**

- During track window updates every six hours
- Coordination increased during wind/weather delay
- Addition rerouting of trains due to exceeding track window

---

**Track Window Video**
Summary

- In-line Replacement
- Winter track window
- 25 hour wind/weather delay
- All planning - Mother nature
- Limited extension to 11 hours

Project Team

Questions