BLACK DOG BRIDGE PROJECT

Robert Mateega, P.E., HDR Engineering Inc., Minneapolis, MN

ABSTRACT:

When Xcel Energy wanted to replace four culverts in the embankment between two cooling lakes at one of their plants with a bridge, it needed a bridge that could be constructed rapidly, as the embankment also carried the railroad spur line used to bring coal to the plant. It was determined that the best solution was to construct a bridge using precast concrete components, as it could be constructed in a relatively short period of time. In addition, through the use of precast concrete components Xcel Energy could be sure that they were getting a bridge with high quality members, as the precast concrete members would be fabricated in a plant with stringent quality control standards, reducing future maintenance costs. The design solution was an 87.83 feet two span prestressed concrete box bridge. Each span had two 42 inch box beams placed side by side to support ballast, a single railroad track and a walkway. The abutments consisted of a precast concrete abutment cap beam with a backwall. The wingwalls were also composed of precast concrete. Each abutment was supported by steel piles welded to steel plates embedded into the concrete abutment cap beam. The pier consisted of a precast concrete pier cap beam supported by steel piles welded to steel plates embedded into the concrete pier cap beam. The bridge was scheduled to be built within a four week window, when the plant was shut down for regular maintenance. To ensure that the bridge was built on time, the contract had incentives for the contractor to finish the bridge on time, and penalties for finishing past the four week window. Without any special equipment, the contractor was able to meet the aggressive schedule, and open the new bridge 10 days early.

Keywords: Accelerated Construction, Creative/Innovative Solutions and Structures, Substructures, Precast.

BLACK DOG BRIDGE PROJECT

INTRODUCTION

When two of four 10-ft diameter corrugated metal pipe culverts in the embankment between two cooling lakes at the Xcel Energy Black Dog Generating Plant in Burnsville, Minnesota collapsed, Xcel Energy knew that they had to replace the culverts before the remaining two collapsed. A possible solution was to replace the culverts with a bridge structure that could handle the increased water flow between the lakes. The replacement bridge had to be built quickly, as the embankment between the two lakes carries the railroad spur line used to bring coal to the plant as well as a second access road to the plant. Also, to minimize construction costs and time, the replacement bridge had to preserve the existing vertical railroad alignment. Finally, Xcel Energy, a private utility company and not a public agency accustomed to managing an inventory of bridges, wanted a high quality bridge with minimal maintenance requirements.

Fig. 1 Aerial View of Project Site

STRUCTURE TYPE SELECTION

Xcel Energy turned to HDR Engineering Inc., who had provided water resources, mechanical and electrical design services at the Black Dog Generating Plant, to use their transportation group to come up with a solution.

HDR looked at various options to replace the culverts, including precast reinforced concrete boxes, a reinforced concrete slab bridge, a precast/prestressed concrete beam bridge, a precast/prestressed concrete box beam bridge, and a steel rolled beam bridge.

The pattern of water flow between the two cooling lakes dictated that the replacement structure be located at the same location as the existing culverts. In addition, the horizontal alignment of the railroad track had to remain the same to avoid costly realignment of the track. The option of building a shoo-fly to divert the coal trains while the replacement bridge was built was also not feasible due to cost and site constraints.

Therefore, the replacement bridge had to be built in the exact same location as the existing culverts, but in a short period of time so as not to disrupt service to the thousands of customers that rely on power from the plant.

The project team determined that the best solution was to construct two bridges, a railroad bridge and a vehicle bridge. The two-bridge option provided the following advantages:

- Design Optimization: Two bridges allowed the structural members of each bridge to be optimized for the Cooper E-90 loading and the HL-93 loading for the railroad and vehicle bridges respectively.
- Accelerated Construction of Critical Bridge: Two bridges allowed for the more critical railroad bridge to be built faster than the vehicle bridge. The railroad bridge was more critical as it was used by trains bringing coal to the plant.
- Maintained Vertical Profiles: Two different bridges allowed both the railroad track and vehicle roadway elevations to remain unchanged, reducing the cost of track and roadway approach work required.

A precast/prestressed concrete box beam bridge with precast concrete substructure units was selected for the railroad bridge, while a precast/prestressed concrete box beam bridge with cast-in-place substructure units was selected for the vehicle bridge.

The precast concrete superstructure and substructure components for the railroad bridge were selected for the speed of construction they allowed, thus not affecting the delivery schedule of coal to the plant. In addition, through the use of precast concrete components, the owner could be assured that they were getting a bridge with high quality members, as the precast concrete members would be fabricated in a plant with stringent quality control standards. Finally, bridges with precast/prestressed concrete components have very few maintenance requirements, thus reducing future maintenance costs.

RAILROAD BRIGE DESIGN

The railroad bridge designed using the AREMA Design Specification had an overall structure length of 88.17 ft, created by two 44-ft-long spans. A two-span bridge configuration was selected, as the superstructure depth required for a single span bridge layout that would span all four 10-ft diameter corrugated metal pipe culverts while preserving the horizontal railroad alignment did not provide a large enough hydraulic opening for water flow between the lakes. The two-span configuration also provided a divider for the water to circulate between the two lakes, which is necessary to meet the cooling water temperature requirements of the plant.

42-in. deep double cell prestressed concrete box beams were selected for the superstructure. The 42-in.-deep double cell concrete beams, designed for a Cooper E-90 loading, preserved the vertical railroad alignment while maximizing the vertical and horizontal waterway opening under the bridge. The design compressive strength of the box beam concrete was 7,000 psi, and the prestressing strands were 0.6-in. diameter 270 ksi low-relaxation strands.

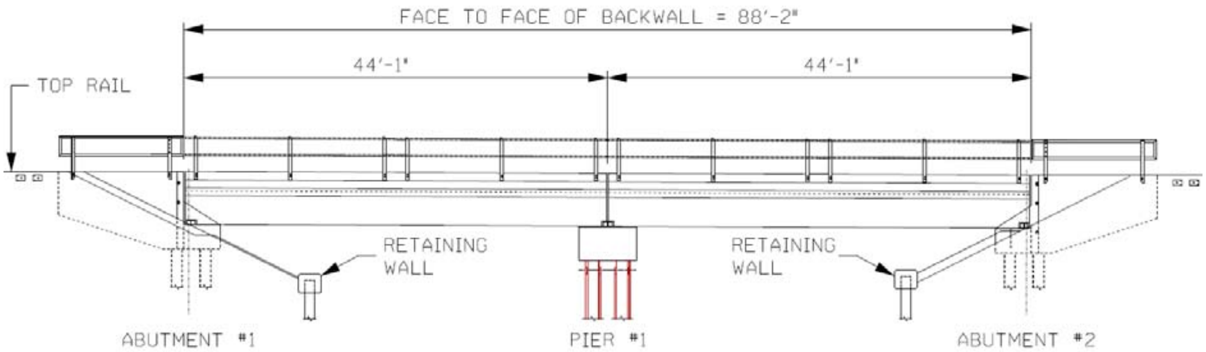

Fig. 2 Railroad Bridge Elevation View

Each span had two box beams placed side-by-side to support ballast, a single railroad track, and a walkway on one side. The side-by-side box beams had the advantage of not requiring falsework to build a slab to support the ballast and track, thus reducing construction time and equipment.

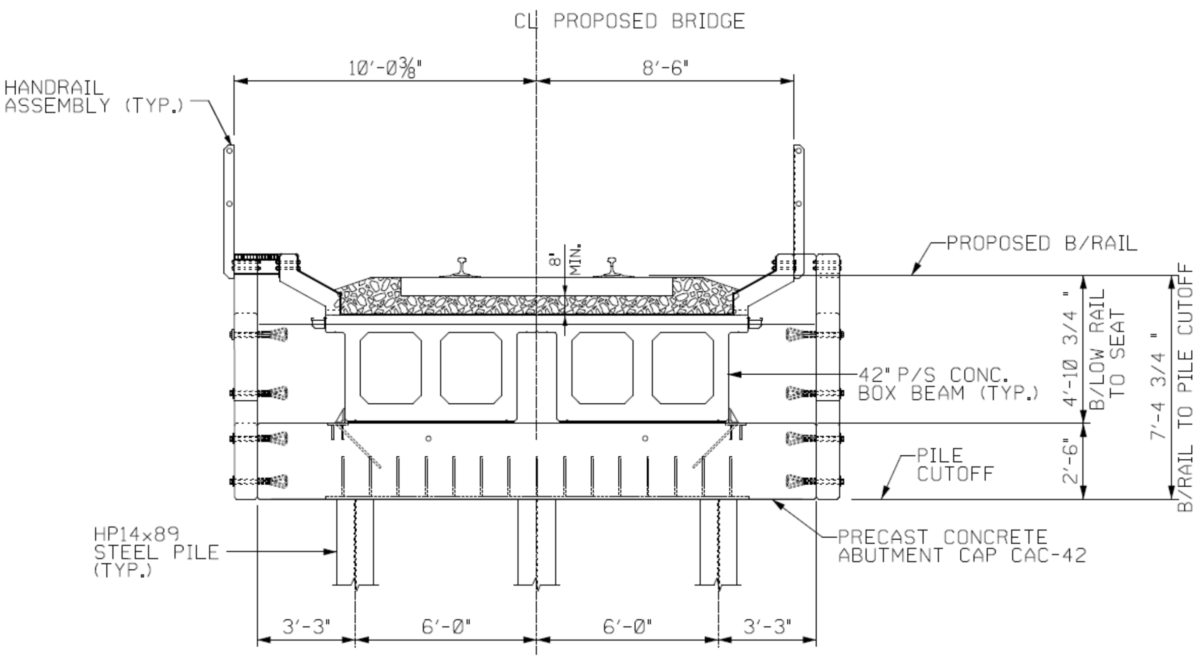

Fig. 3 Railroad Bridge Typical Section at Abutment

Each of the non-integral abutments consisted of a precast concrete abutment cap beam including backwall. The abutment cap beam was 2.50 ft by 6.00 ft by 18.50 ft long, while the backwall was 5.56 ft by 1.33 ft by 18.50 ft long. The design compressive strength of the precast concrete abutment cap beam and backwall was 4,000 psi and they were reinforced with Grade 60 reinforcing bars.

Combined together each abutment cap beam and backwall had a total weight of 28.2 tons, and had four lifting loop inserts for lifting during transportation and construction. The wingwalls were also composed of precast concrete with 4,000 psi concrete and Grade 60 reinforcing bars. Each wingwall was attached to the abutment cap beam using six coil bolts fastened to double-flared coil inserts embedded in the abutment cap beam. Each abutment was supported by HP 14 x 89 steel piles welded to ¾" thick steel plates embedded into the bottom of the precast concrete abutment cap beam using ¾"-diameter by 1.50 ft anchor bars.

The two-span bridge configuration required that the pier for the bridge be located directly over one of the collapsed existing 10-ft diameter corrugated metal pipe culverts. As the collapsed culverts had been filled with flowable fill to prevent settlement of the railroad track and access roadway, the culvert had to be removed to construct the pier.

The pier consisted of a precast concrete pier cap beam that was 3 ft by 6 ft by 15 ft long and weighed 24.3 tons, and was supported by eight HP 14 x 89 steel piles welded to steel plates embedded into the precast concrete pier cap. Diagonal cross bracing consisting of channel sections was used to brace the steel pile bent.

The pier design utilizing a precast concrete pier cap on steel piles was determined to be more cost effective and faster to build than using a precast concrete pier cap on precast concrete columns.

To protect the steel piles from debris floating between the lakes, the steel pile bent was enclosed by steel plates on all four sides, forming a box measuring 13.25 ft by 4.50 ft in plan that extended from the bottom of the pier cap to 5 ft below the bottom of the channel. The steel plates also helped to divide the channel between the two lakes, helping with water circulation.

Sheet piling retaining walls topped by concrete caps were located in front of each abutment. The sheet piling was used both to protect the abutments, and create a channel with vertical edges, allowing more water to flow between the two cooling lakes.

Although scour was not anticipated to be a problem, the entire channel bottom between the two lakes was lined with 18" of rip rap to as a precautionary measure.

VEHICLE BRIGE DESIGN

The vehicle bridge designed using the AASHTO LRFD Bridge Design Specification was also a two-span configuration with two 44-ft-long spans and an overall structure length of 92.50 ft. The two-span bridge configuration for the vehicle bridge matched the railroad bridge.

Given that the demand for a HL-93 loading is less than that for a Cooper E-90 loading, 27-in. deep single cell box prestressed concrete box beams were adequate for the vehicle bridge, as opposed to the 42-in. deep double cell prestressed concrete box beams required for the railroad bridge. The 27 in. deep single cell box beams were AASHTO Type BI-36 beams with final concrete compressive strength of 5,000 psi and 1/2-in. diameter 270 ksi low relaxation prestressing strands.

The superstructure consisted of seven AASHTO Type BI-36 beams placed side-by-side and topped with a cast-in-place concrete slab that varied in thickness from 7 inches at the crown to 4 inches at the edges. The roadway width was set at 21ft per the City of Burnsville fire code in order to accommodate fire trucks in case of an emergency. The side-by-side boxes again had the advantage of not requiring falsework to construct the cast-in-place slab.

Each side of the vehicle bridge had a barrier topped by a 6-ft chain link fence, to prevent fishing and jumping off the bridge.

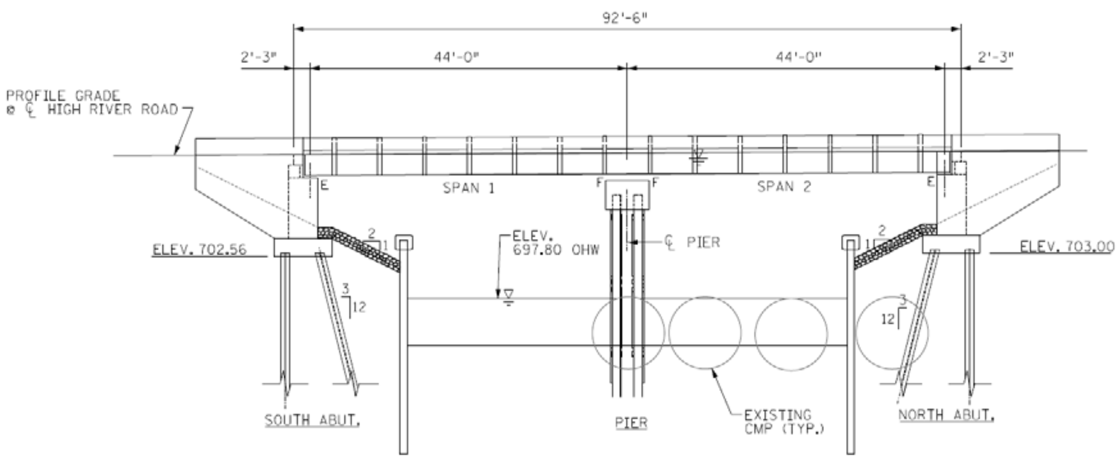

Fig. 4 Vehicle Bridge Elevation View

The abutments for the vehicle bridge were also non-integral. Unlike the railroad bridge, cast-in-place concrete was used for the substructure of the vehicle bridge. Cast-in-place concrete was required due to the abutment stem measuring 8.40 ft from the pedestal elevation to the top of footing, which would have added greatly to the weight of a precast concrete abutment. The tall abutment stem was due to the higher elevation of the access road vertical profile and the shallower superstructure depth of the vehicle bridge.

The steel piles for the vehicle bridge were HP 10 x 57 piles driven to bedrock instead of the HP 14 x 89 steel piles used for the railroad bridge.

Similar to the railroad bridge, the pier for the vehicle bridge consisted of a pile cap on eight HP 14 x 89 steel piles driven to bedrock, the difference being cast-in-place concrete was used for the pier cap. As speed of construction for the vehicle bridge was not as critical and cast-in-place concrete was already being used for the abutments, it was determined that a precast concrete pier cap was not necessary for the vehicle bridge.

CONSTRUCTION

The railroad bridge was scheduled to be built within a four week window when the Xcel Black Dog Generating Plant was shut down for its regular maintenance. To ensure that the bridge was built on time, the contract had incentives for the contractor to finish the bridge within four weeks, and penalties for finishing past the four week window. The bonus and penalty were calculated on a daily basis, based on how many days early or late from the scheduled construction completion date the contractor opened the bridge to rail traffic.

The precast concrete components of the bridge were fabricated by Coreslab Structures, Inc. of Omaha, Nebraska, and the bridge construction prime contractor was Ames Construction, Inc. of Burnsville, Minnesota.

To construct the bridge, the contractor first removed the two culverts that had collapsed and built a cofferdam in their place. Within the cofferdam, the contractor then drove the piles to bedrock for the pier. The use of a cofferdam in the location of the two collapsed culverts allowed the other two operational culverts to remain in service while the bridge was constructed.

The HP 14 x 89 steel piles for the abutments were driven through the embankment to bedrock followed by the sheet piling for the retaining walls in front of each abutment.

Following pile driving, the precast concrete abutment cap beams and pier cap beam were installed. The use of the precast concrete members drastically reduced the amount of time required to construct the substructure units, by eliminating the time to set forms, set reinforcing steel, pour concrete, cure concrete, and strip the forms. According to Justin Gabrielson, the contractor’s Project Manager on the job, a regular cast-in-place abutment would have taken nine days from when the piles were in place to stripping the forms. Instead the task took only four days using the precast concrete components.

Fig. 5 Driving Pile at Pier

The heaviest precast concrete substructure member was only 28.2 tons, and all precast concrete members had lifting loops cast into them. Therefore, the contractor was able to use their regular construction equipment to set the precast concrete substructure members and did not have to bring in special equipment for the project, helping to keep costs down. One critical step in the construction of bridges using precast concrete components on steel piles is ensuring full contact between the pile and the embedded steel plate in the precast concrete component. Therefore, it is important to have a contractor such as Ames Construction, who has significant experience constructing bridges using precast concrete components on steel piles, to ensure proper construction.

Once the abutment, pier, and sheet pile retaining wall were in place, the contractor removed the cofferdam and excavated the channel to the limits of the vehicle bridge. This was done as it was faster and more efficient to excavate the channel without the beams being in place. One of the remaining 10-ft diameter culverts was also removed at this time, while the other was left in place to be filled with flowable fill at the end of the construction project to prevent it from collapsing in the future. The fourth culvert was left in place, as it was behind the sheet piling retaining wall. The ratio of the front battered steel piles for the roadway bridge abutment was modified from 12:3 to 12:1.5 so that the front piles could clear the culvert that was left in place.

The 42-in.-deep double cell prestressed concrete box beams were installed after the channel was excavated. Installation of ballast, track ties, track, sidewalk and handrail quickly followed installation of the prestressed concrete box beams.

Fig. 6 Railroad Bridge Precast/Prestress Box Beam Installation

The contractor was able to construct the railroad bridge in 20 days from track out to track in-service, and thus collected 10 days worth of bonus incentives for finishing early. According to Jon Lahti, Xcel Energy Plant Superintendent, the railroad bridge was built rapidly, well within budget, and on schedule. Any delay in opening the railroad bridge on time would have been very costly to the owner and their customers that rely on power from the plant.

Subsequent to building the railroad bridge, the vehicle bridge was built following the same sequence of events used for the railroad bridge, with the difference being the additional time required to build the cast-in-place substructure components and cast-in-place concrete slab.

CONCLUSION

Using precast concrete components for the superstructure and substructure of a bridge is a fast, efficient and cost effective way to construct a bridge structure. The owner was able to quickly build a replacement railroad bridge at their Black Dog Power Generating Plant using precast/prestressed double cell box beams for the superstructure and precast concrete components for the substructure units without disrupting power service to their thousands of customers. Doing so allowed them to complete the bridge construction during the plant's regular four week shut down for regular maintenance rather than scheduling an additional outage. Due to the high quality of precast concrete products, the owner also got a bridge structure with low future maintenance costs and that will last for a very long time.

Fig. 7 Black Dog Bridges