MASSENA LATERAL BRIDGE SLIDE CASE STUDY

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ABSTRACT

Accelerated Bridge Construction (ABC) systems are needed that allow components to be fabricated either off-site or on-site and moved into place for quick assembly while minimizing disruption to traffic. The use of prefabricated bridge systems can minimize traffic disruption, improve work-zone safety, minimize disruption to the environment, improve constructability, increase quality and lower life-cycle costs. A lateral bridge slide is one type of ABC project where a bridge superstructure is constructed adjacent to an existing bridge and slid transversely into its final position once the existing bridge is removed.

This paper will present the preliminary research, design, and constructability review for the first application of a lateral bridge slide in the State of Iowa. The project utilizes a precast concrete footing founded on driven H-piling for the substructure. The superstructure is a 120’ single span utilizing 45” deep, pretensioned, prestressed concrete bulb tee girders and a cast-in-place deck. The superstructure will be constructed adjacent to the existing bridge and slid into position in a short duration critical closure of the roadway. The project is located on Iowa 92 just west of the City of Massena in Cass County, Iowa. The bridge has been designed by the Iowa Department of Transportation.

Key words: Accelerated bridge construction, bridge construction, bridge replacement, precast concrete, innovative bridge design, lateral bridge slide

INTRODUCTION

The Iowa Department of Transportation (DOT) recognizes that maintaining mobility on our transportation network is a key component for increasing the vitality of the State. Like other states, Iowa maintains an aging infrastructure that is continually undergoing repair and improvement. Bridge repair and replacement projects can greatly affect the transportation network and are treated with a high level of importance. In the past ten years Accelerated Bridge Construction (ABC) has started to take root nationally and in Iowa as well. ABC techniques are used to reduce the time to construct bridges as well as the duration of the impact on the transportation network. Benefits include a reduction in costs to users of the transportation network which are realized in reduced out of distance travel, delay costs due to construction congestion and reduced operating speeds, and in some cases, losses due to impacts to access of local business. Another benefit of using ABC techniques is the potential increase in safety of the project. Generally the ABC techniques reduce the duration of exposure of both the construction worker and the motorists to construction zones which can carry a higher risk of collisions.

The Iowa DOT has been developing and implementing various methods of ABC since 2002 including the use of precast concrete substructure elements, modular superstructure units, precast approach paving, and full-depth precast deck panels. In this paper we will describe the latest iteration of ABC development in Iowa which is a prefabricated bridge superstructure move using a lateral slide.

The project is a bridge replacement located in Cass County, Iowa on State Highway IA-92, just west of the town of Massena. The existing bridge is a 40’ long, single span, steel I-beam bridge originally constructed in 1930 and widened in 1949. The existing bridge is classified as structurally deficient and is currently posted to restrict heavy loads. The existing bridge is 30’ wide and is not conducive to staged construction in order to maintain traffic during the replacement.

Conventional options for maintaining traffic during the bridge replacement include a temporary run-around structure or a detour. Run-around structures have been used in Iowa since the 1970’s and the Iowa DOT owns three spans of reusable run-around superstructure. Run-around structures are not considered cheap, but can be relatively cost effective in certain circumstances. In this case all three of these temporary spans would’ve been needed and this was not an option as two spans were already committed to another project for the 2013 summer construction season.

The official detour at this site is a 13 mile route that results in 7 miles of out-of-distance travel for the roadway users. During concept development it was estimated that the conventional “remove-and-replace” construction technique would result in the detour being in effect for up to 180 days, which would encumber an additional user cost of $437,000. Alternatively, with the bridge slide technique that has been developed for this project, the detour has been reduced to a 9 day critical closure where the detour will be in effect, and which reduces the user costs to $22,000. Those user costs also include direct costs for signing the detour and payments to the county for county road maintenance.

The replacement bridge will utilize precast abutment footings founded on a deep foundation of driven H-piling. The wing walls are also precast and founded on driven H-piling. The superstructure consists of a single, 120'span, pretensioned, prestressed concrete bulb tee C beams (BTC120) with zero degree skew and an 8" cast-in-place concrete deck. The superstructure will be constructed on temporary bents adjacent to the existing bridge and completed prior to the demolition of the existing bridge shown in Figure 1 – New Bridge Superstructure Adjacent to Existing Bridge.

Figure 1 – New Bridge Superstructure Adjacent to Existing Bridge

After the contractor has completed casting and curing all of the prefabricated elements and the weather looks favorable for construction, the critical closure will be implemented. The critical closure is defined as the time period that IA 92 is out of service and traffic is detoured. The contract specified a maximum critical closure duration of nine days and includes an Incentive/Disincentive (I/D) value of $10,000 per day. The contractor can earn up to 4 days of incentive for re-opening the roadway early and there is no maximum disincentive for re-opening the roadway late after 9 days.

The major construction activities anticipated to occur during the critical closure includes the following:

- Detour traffic
- Demolish existing bridge
- Grading
- Drive steel H-piling

- Place precast abutment footings
- Place precast wing walls
- Cast high early strength concrete in precast-to-H-piling connection pockets
- Move prefabricated bridge superstructure (sliding is assumed but not required)
- Backfill behind abutment
- Approach paving
- Install approach guardrail
- Longitudinal grooving and pavement markings
- Open roadway

The Iowa DOT has utilized precast abutment footings and precast wing walls on past ABC projects and feels confident in the design and use of those components. However, the prefabrication of the bridge superstructure adjacent to the existing structure and moving it into its final position is a first for the Iowa DOT.

RESEARCH

The Federal Highway Administration (FHWA) and a number of states have been investigating ABC methodologies to increase the number of options available for routine bridge replacement projects. One relatively new methodology for highway bridges is the horizontal skidding or sliding method. At the time the Iowa DOT started considering the use of the sliding method for the Massena Bridge replacement project the DOT was aware of six states that had either completed or had planned a horizontal bridge slide. Those states included Utah, Oregon, Wisconsin, Nevada, Washington and Massachusetts. The Iowa DOT was aware of Utah's well-deserved reputation for successful ABC projects, especially through the use of prefabricated bridge superstructures moved into place using Self-Propelled Modular Transporters (SPMT), and therefore contacted Utah to see if they were planning on any lateral slide projects for the 2012 construction season.

Fortunately, Utah DOT had planned a bridge slide project on I-80 near the town of Wanship, UT. Iowa partnered with the FHWA and Utah DOT to arrange a visit to the project site during construction. The meeting and site visit were instrumental in the Iowa DOT gaining the confidence that this technology could be utilized to improve bridge replacement delivery in Iowa. The Utah DOT had designed the Wanship Bridge and also provided a forum to ask questions of the designer, contractor and contractor's consulting engineer. The Wanship Bridge was closed to I-80 traffic, and the new bridge was slid into position, shown in Figure 2 – Utah DOT Wanship Bridge Slide. The entire closure of I-80 lasted less than 18 hours. The existing bridge at the Wanship site was a three span bridge with spill through abutments and the replacement was a single span bridge with high abutments and jump spans for the approaches bearing on grade beams. The new substructure was constructed underneath the end spans of the existing bridge.

Figure 2 – Utah DOT Wanship Bridge Slide

Following the successful Utah DOT Wanship Bridge slide site visit, the Iowa DOT hosted an FHWA Accelerated Bridge Construction Prefabricated Bridge Elements & Systems Lateral Slide Workshop in Ames, IA. The FHWA sponsored the workshop and arranged for subject matter experts to give presentations on completed lateral bridge slide projects. The Iowa DOT and Minnesota DOT also gave presentations for upcoming ABC projects – namely the Massena Bridge slide (Iowa) and TH 61 over Nymphara Lane near Red Wing (Minnesota), respectively. The conference allowed for subject matter expert feedback on the two project proposals. Participants in the workshop included hydraulic engineers, structural engineers, resident construction engineers, contractors and consultants. There was considerable discussion regarding the Massena Bridge replacement project that was ultimately incorporated into the final concept and design of the bridge.

DESIGN

The structural design of this project was performed by the Iowa DOT in accordance with the AASHTO LRFD Bridge Design Specifications, 5th Edition, 2010 and the Iowa DOT Bridge Design Manual (1). The soil profile at the site consists of soft to very firm glacial clays to a depth of approximately 100' below the roadway surface where the soil borings were ended. The proposed structure will utilize a deep foundation consisting of driven steel H-piling.

For typical zero degree skew, pretensioned, prestressed concrete beam bridges up to 575' in length, the Iowa DOT prefers to use integral abutments[1]. Two integral abutment options were investigated during the design phase, including one which combines the footing and superstructure diaphragm into a single unit to be laterally slide over the tops of the H-piling and lowered onto the pile pockets shown in Figure 3 – Integral Abutment Option 1. Pile pockets are formed using 24" diameter, galvanized, corrugated metal pipe sections. These pocket form details have been previously tested[2] to ensure adequate bond and shear capacity. The pile pockets would then be filled with a grout or self-consolidating concrete after the superstructure was lateral slid and lowered into its final position.

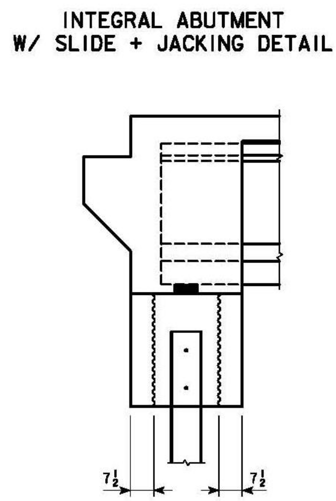

Figure 3 – Integral Abutment Option 1

Multiple concerns were raised with Integral Abutment Option 1 including the blind lowering of the entire bridge over the piling that had already been driven, adequate grouting of the closed pile pockets, the substantial weight of the system being lowered and the contractor having to establish a suitable work platform on which to slide and lower the bridge.

The second integral abutment option considered involved the use of a precast abutment footing that was connected to the superstructure using reinforcing with mechanical splicers and a cast-in-place diaphragm as shown in Figure 4 – Integral Abutment Option 2.

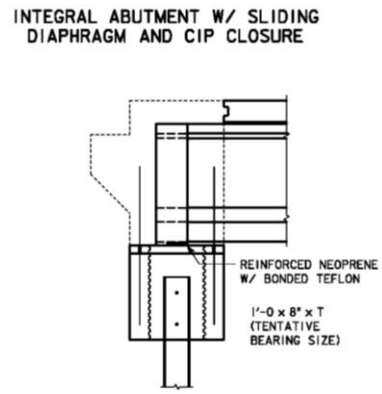

Figure 4 – Integral Abutment Option 2

The primary concern noted with option 2 was the additional construction step of the cast-in-place closure for the diaphragm that would be required to occur on the critical path. Integral abutment option 2 has been used on several Iowa DOT ABC jobs with great success but ultimately the short duration of the critical closure, combined with the extra step on the critical path eliminated this option from further consideration.

As an alternative, the designer investigated the use of a semi-integral abutment type. A semi-integral abutment is one in which the footing remains fixed and the superstructure is allowed to expand and contract over the top of the fixed footing with changes in ambient temperature. Semi-integral abutments are a good compromise between an integral abutment and a stub abutment which is a fixed abutment with an expansion joint to accommodate superstructure movement. The Iowa DOT has used semi-integral abutments on a limited basis, typically to accommodate special site conditions such as rock near the ground surface. A stub abutment was definitely not considered for this location due to the maintenance required to keep expansion joints free of leaks and the rapid abutment and beam end deterioration that typically occurs once an expansion joint is compromised. Ultimately the design utilized a semi-integral abutment.

The footing consists of precast concrete footing with pockets to accommodate driven steel H-piles. The design utilized HP14x117 piling which offered dual advantages over the HP10x57 piling commonly used by Iowa DOT bridge designers. First, the larger size required fewer piling to achieve the required bearing capacity and thus reduces the number of connections between the piling and precast abutment footing and the time spent driving piling. The second advantage of the HP14x117 piling was the increased stiffness in strong axis bending to help ensure abutment footing fixity and avoiding the need to batter piling. The final design used the semi-integral abutment option shown in Figure 5 – Semi-integral Abutment.

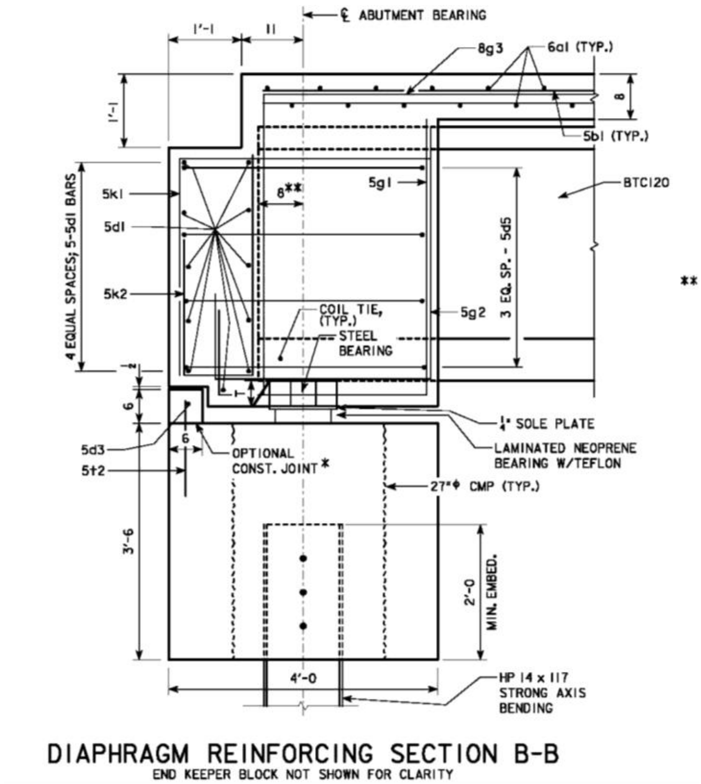

Figure 5 – Semi-integral Abutment

Precast abutment footings have been used on several Iowa DOT ABC projects which were founded on driven H-piles. The original design was done in 2005 and involved laboratory testing by Iowa State University. Given the larger H-piling for this project, additional full-scale laboratory testing is underway at Iowa State University. The testing in this case has multiple purposes. First, due to the larger H-piling being used, larger diameter CMP is being used to maintain the pile driving construction tolerances. Iowa State University will be load testing the larger piling and pocket details to verify assumptions about design capacity.

In addition, the piling were designed and detailed with shear studs welded to the webs of the H-piling and, based on feedback from previous projects, this is a detail that the contractors have found difficult to construct in the field. The primary difficulties with this detail include: pile driving length is not known at the start of driving so that studs are not welded until piles are cutoff after driving, not all general bridge contractors have field-accessible stud welding guns and a fillet weld is difficult to install in the space between the flanges and requires a certified welder. The testing program is designed to evaluate the ultimate strength of the embedded H-piling and concrete-filled pocket to determine the effectiveness of the studs or if they can be eliminated from future projects. Currently the plans detail an alternate to using welded studs to alleviate some contractor concern. The alternate is a high strength threaded rod which is passed through a drilled hole in the pile web instead of welded studs, shown in Figure 6 – Stud Alternate. There is still difficulty with constructing the threaded rod alternative as the space between the

H-pile flanges is limited and the contractor needs to fit a magnetic drill in between the flanges to drill the hole in the H-pile.

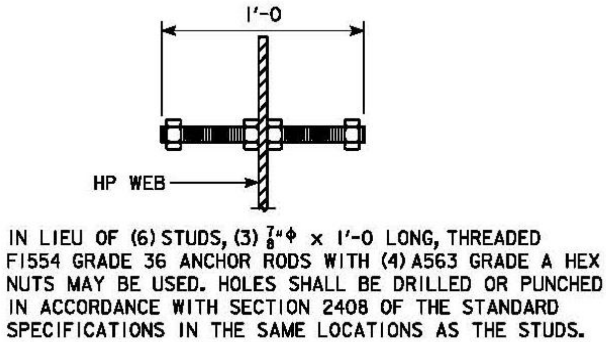

Figure 6 – Stud Alternate

The wing walls on the project are designed as fully precast with the bridge barrier rail end sections precast on top of them. The precast wing wall detail for this project is not a first use for an Iowa DOT bridge and was used previously for the US 6 over Keg Creek Bridge a modular ABC design in 2011. The Precast wing wall details are shown in Figure 7 – Precast Wing Wall. The precast wing walls are supported by HP14x117 piling similar to the precast abutment footing.

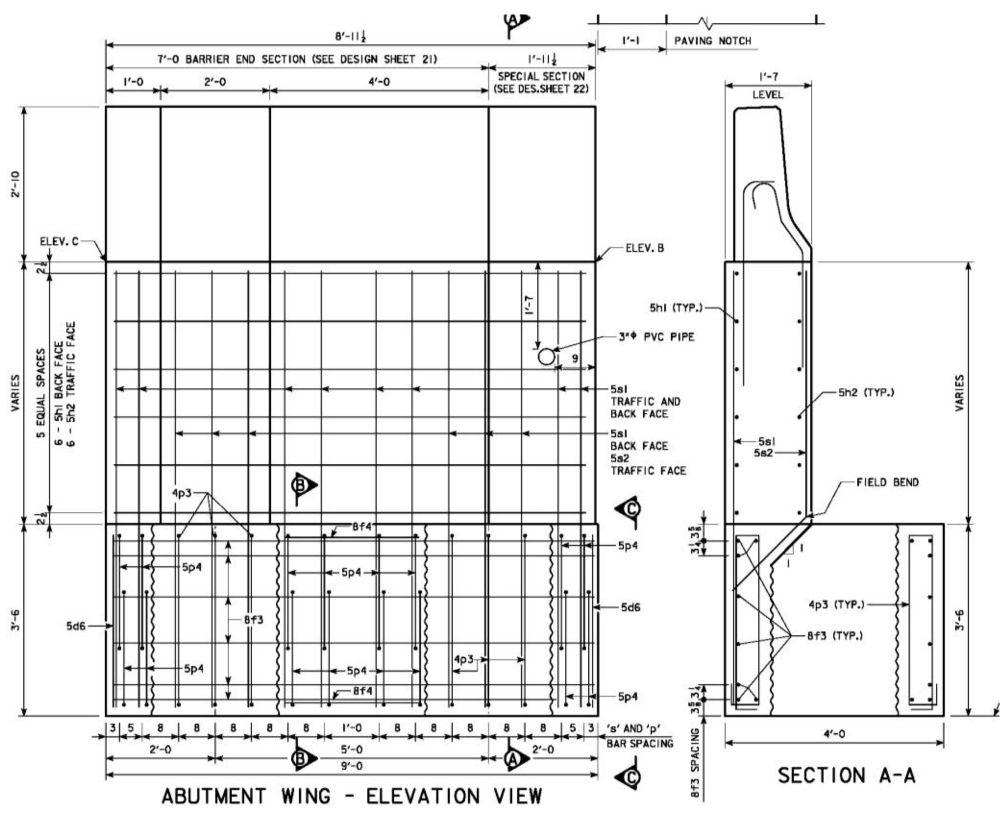

Figure 7 – Precast Wing Wall

The project utilizes the Iowa bulb tee "C" beam standard for 120' long beams. The beams are 45" tall section that has been widely used in Iowa since 2004. A typical cross section for the beam is shown in Figure 8 – Iowa BTC Beam Cross Section. The BTC beam utilizes 0.6" diameter low relaxation prestressing strands.

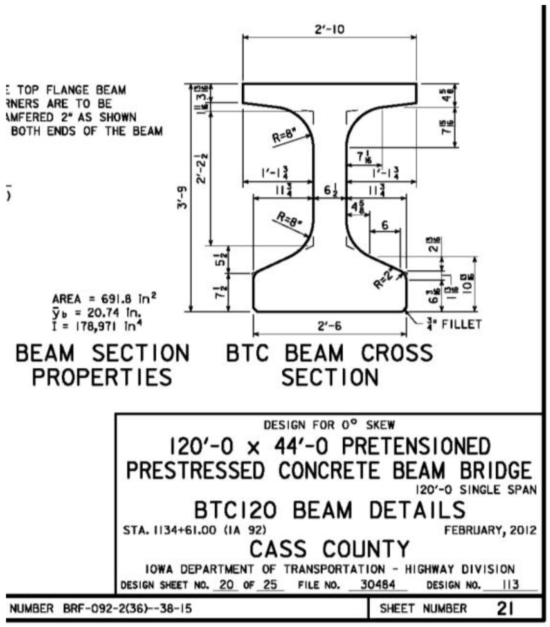

Figure 8 – Iowa BTC Beam Cross Section

The Special Provisions for Prefabricated Bridge Superstructure Move allow different methods for the move. These include sliding the span on Polytetrafluoroethylene (PTFE) bearings, heavy duty rollers and Self-Propelled Modular Transporters (SPMT). The plans illustrate a conceptual design using the PTFE slide option and a full design, by a licensed contractor's engineer with complete submittals is required. See Figure 9 – Prefabricated Bridge Superstructure Slide for a rendering of the PTFE slide option.

Figure 9 - Prefabricated Bridge Superstructure Slide

The sliding bearings consist of laminated neoprene bearings with a bonded PTFE layer. The bottom of the prefabricated superstructure contains a stainless steel sole plate which acts as the sliding shoe shown in Figure 10 – Sliding Shoe Detail. The sliding surface is typically lubricated with common dish soap and the kinetic coefficient of friction has been reported to be quite low from experience with previous projects. Iowa State University is tasked with laboratory testing prior to construction to measure the static and kinetic coefficient of friction.

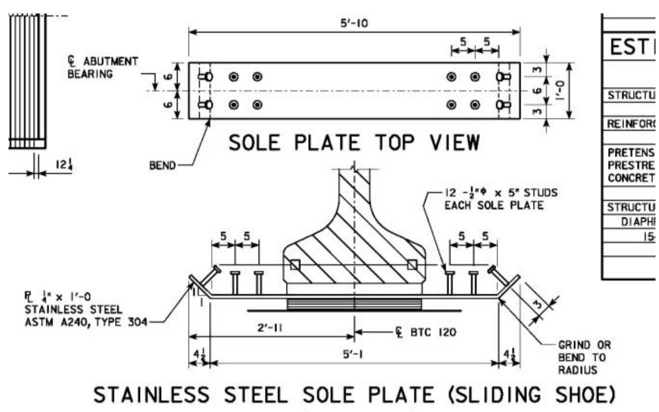

Figure 10 – Sliding Shoe Detail

INDUSTRY PARTNERING

Prior to completion of the design, an industry constructability review meeting was held with five Iowa bridge construction general contractors. The meeting was also attended by various specialty subcontractors and Iowa DOT personnel. At this meeting, a presentation on the Utah Lateral Bridge Slide Experience was given by a Utah contractor and a Utah consulting engineering firm with experience in Utah DOT lateral bridge slide projects. The intent of the presentation was to provide Iowa contractors with a number of project success stories and lessons learned from lateral bridge slide projects performed in Utah. A preliminary set of design plans for the Massena Bridge project was distributed prior to the meeting for contractor review and comment. Additionally a presentation on the project details and major design decisions and concerns was given by the Iowa DOT.

As a result of the constructability review, a number of improvements were made to the final plans prior to advertising that likely saved the Iowa DOT significant money and saved the awarded contractors considerable grief. Improvements included reconfiguring the jacking pockets to give the contractors more flexibility in lifting operations, clarifying the special provisions contract items and submittal items, separating the bearings from the beams bid item in order to simplify the process for changing move types, and clarifying the contract period requirements to give the contractor flexibility when working outside the critical closure. In order to ensure a level playing field for all bidders, presentations, plans and minutes from the constructability review meeting were made available to all bidders prior to the letting of the project.

A pre-bid meeting was held prior to the letting for all interested contractors. The Iowa DOT presented some of the unique details from the plans and special provisions. A 3D visualization video was produced to illustrate a possible construction sequence and to help the contractor visualize the project and clarify the design intent. The video can be viewed at http://www.iowadot.gov/MassenaBridge/index.html.

TECHNICAL REVIEW

Based on their experience with bridge sliding projects in Utah and elsewhere in the US, a team of consulting engineers from Utah were contracted to provide technical review of the contract documents prior to letting and to provide onsite construction observation and assistance during the sliding operation. This review provided Iowa DOT with additional confidence that the project can be safely constructed within the available critical closure period.

CONCLUSION

The Massena lateral bridge slide project represents a great opportunity for the Iowa DOT to continue developing ABC techniques for use on future projects. The use of precast components and the prefabricated superstructure slide is an ABC method that does not require a large inventory of specialized equipment and can reduce significantly construction impact on roadway users.

The project was let on April 16, 2013 and awarded to the low bidder from Indianola, Iowa for $1,346,647.90. Based on initial meetings with the awarded bridge contractor their intent is to use 100-ton capacity rollers to move the superstructure in position. These rollers were first used to roll a railroad span in 1970 and have been stored by the contractor since that time.

Construction of the prefabricated components and the prefabricated superstructure will take place during the summer of 2013. The critical closure and prefabricated superstructure move will be scheduled by the contractor and in anticipated to occur at the end of summer 2013 or early fall of 2013, see Figure 11 – Completed Bridge Replacement.

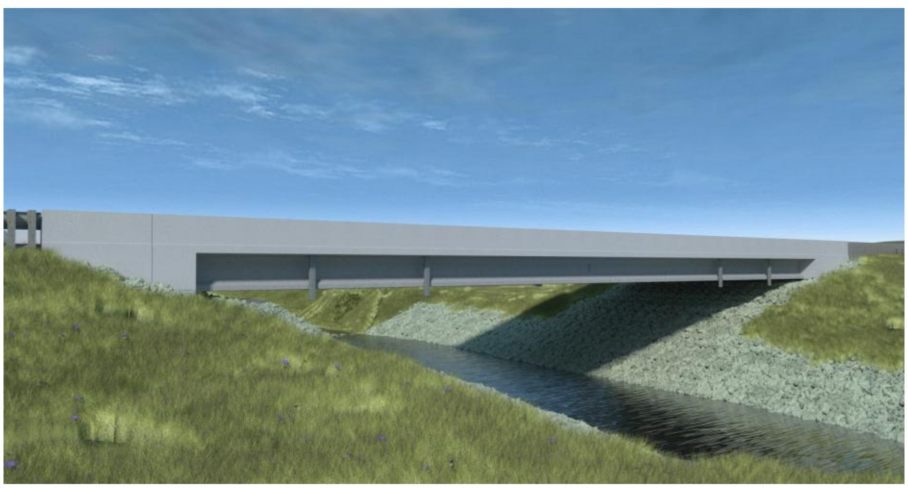

Figure 11 – Completed Bridge Replacement

Bridge unit cost on this project using the Iowa DOT calculation methodology is $112/SF. Typical PPC bulb tee beam bridges in Iowa are currently estimated at $85/SF. Based on these values, the calculated premium on the ABC technique in this case is 32% but that additional cost is greatly offset by the savings in user costs due to the reduction in the duration of out-of-distance travel. The user costs for traditional construction exceed the user costs for the ABC method by $415,000, if these user costs were factored into the project costs, the ABC bridge would actually show a net savings of cost over the conventional construction approach. In addition, advanced ABC cost metrics that include factors such as opportunity cost and safety costs would show even greater savings by using the ABC methodology.

The Massena bridge project illustrates that an ABC project does not necessarily require expensive equipment or the use of overly rigorous design calculations to develop a cost-effective, easy-to-construct bridge that will ultimately save Iowa taxpayers time and money during construction. Bridge owners across the US can learn a great deal from this example and should consider a similar approach for their upcoming bridge replacement projects.

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