

SABULA ACCELERATED BRIDGE CONSTRUCTION CASE STUDY: US 52 OVER MISSISSIPPI RIVER OVERFLOW

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ABSTRACT

This paper details the implementation of Accelerated Bridge Construction (ABC) by the Iowa Department of Transportation (DOT) on the US 52 Bridge over Mississippi River Overflow. The Iowa DOT is in the process of completing an ABC design for the proposed replacement of the existing 342' x 20' steel high truss structure originally constructed in 1933.

When the structure is out of service the detour is 36 miles, all of which is considered out-of-distance travel. The Iowa DOT has a strong desire minimize this disruption and inconvenience to traffic mobility during the bridge replacement. The project complexity is amplified by a deep scour hole adjacent to the existing bridge in the Mississippi River. Environmental and permitting factors all but eliminated other conventional methods for maintaining traffic such as staged construction or realignment and construction adjacent to the existing bridge, leaving ABC techniques as the only reasonable alternative to minimize traffic disruption.

ABC techniques anticipated to be utilized include drilled shaft foundations outside the footprint of the existing bridge, straddle bents using a precast pier cap or cast-in-place cap alternate, partial depth precast deck panels and an Incentive/Disincentive contract period for the critical closure when the bridge is out of service.

Additionally, the paper will examine the decision making process for selecting the appropriate ABC tier for the project. Iowa DOT management has proposed an ABC solution in-between a mobility impact time tier 3 and tier 4 solution. The project goal is to complete construction within a four to six week critical closure.

Keywords: Accelerated Bridge Construction, Rapid Renewal, Precast Concrete, Prefabricated Bridge Elements and Systems

INTRODUCTION

Highway US 52 runs over the Mississippi River Overflow area. Replacing a bridge over this area presents unique challenges to maintaining the Iowa DOT's transportation customer's mobility. The bridge is located on the northern edge of the City of Sabula, a Mississippi River town located on an island, and serves as a connection between the City of Sabula and Savanna, Illinois. The Island City of Sabula shown in Figure 1, Google Maps, 2014 (1) is connected to Illinois by one route, US 52 and connected to the main land of Iowa by two routes, US 52 and 47th Street. Sabula has the distinction of being the only city in the State of Iowa that is an island. The population of Sabula is given as 576 based on the 2010 Census Bureau (2) data.

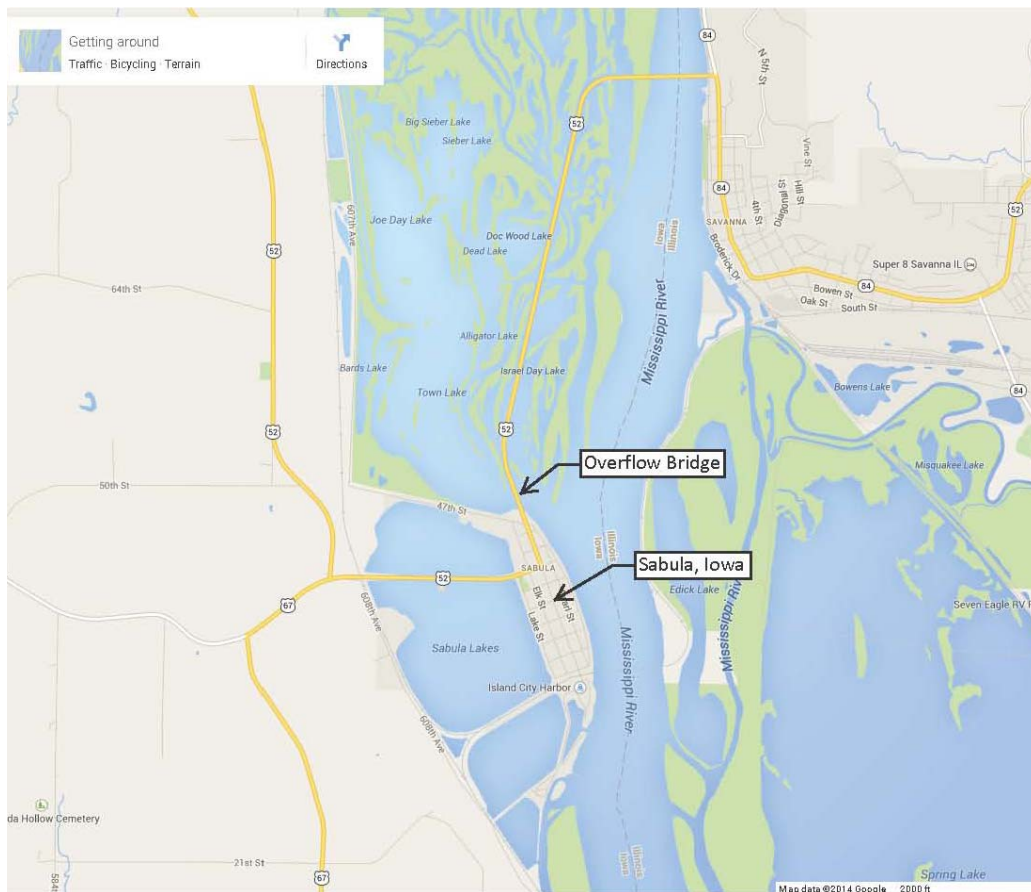


Figure 1 – Map of Sabula, Iowa

The existing Mississippi River Overflow Bridge is a 342' x 20' steel high truss bridge originally constructed in 1933. The bridge approach spans deck was replaced in 1985. It is classified as structurally deficient, functionally obsolete and fracture critical. Steel truss members show many areas of section loss. Bridge rehabilitation was not considered as a viable option and the project was selected for bridge replacement. North of the US 52 Bridge over the Mississippi River Overflow US 52 travels north over a causeway until turning east to the main Mississippi River crossing. The Illinois DOT is the lead state for the Mississippi River border bridge a 2,482' x 20' truss bridge and is currently designing a replacement bridge project tentatively scheduled for a

June 2015 letting. The Illinois DOT is planning to construct the replacement bridge on an adjacent alternate alignment in order to maintain traffic mobility.

While staged construction or construction of a replacement structure on an adjacent alternate alignment is typically an effective way to maintain transportation customer's mobility, it was not a feasible alternative for replacement of the US 52 over Mississippi River Overflow Bridge. Both the staging alternative and the construction on an adjacent alignment had environmental and ROW impacts that were highly undesirable. Therefore, the replacement structure had to be on the same alignment as the existing bridge. This paper will discuss the selection of Accelerated Bridge Construction (ABC) for the project, the ABC tier selected, the ABC design details selected and the preliminary design constructability review process.

ABC AS THE PREFERRED ALTERNATIVE

The use of ABC techniques is still an emerging technology within the State of Iowa bridge construction industry. The Iowa DOT has completed nearly a dozen ABC projects to date using various ABC technologies. ABC project technologies used have included Slide-In Bridge Construction (SIBC), modular units, precast concrete substructure components and full-depth precast concrete deck panels. Momentum and experience continues to increase for ABC, but use of this technology is still not a routine practice. Selection of the use of ABC technologies are on a case-by-case basis with about 5% of bridge replacement projects selecting ABC as the preferred construction alternative. Many bridge replacement projects are constructed with staged construction, on a new alignment or with a full roadway closure and detour in order to maintain traffic.

Iowa DOT developed a Draft ABC Policy (3) that after a year of vetting has been moved into the Iowa DOT LRFD Bridge Design Manual (4) on July of 2014. The policy outlines the decision making process for selecting projects to use ABC technologies. There is a two-step decision making process that initially scores bridges on their suitability for ABC. The first stage scoring criteria is based upon Average Annual Daily Traffic (AADT), out of distance travel, daily road user costs and economy of scale. Each item has a scoring rubric. The scores are tallied and weighted to resolve into an ABC score out of 100 possible points. Bridges with an ABC score of over 50 should be considered for ABC. The Sabula Mississippi River Bridge scored a 52 in the first stage decision making process indicating that further consideration should be given to ABC. While AADT on US 52 is low at approximately 2,300 vehicles per day, the out of distance travel is very high with a detour of 36 miles all of which is considered out of distance travel. Had this bridge been below the ABC consideration threshold, the District may have still requested an ABC solution to be considered because of the long detour to cross the Mississippi River.

With the proposed bridge replacement project passing the first-stage decision making process the Iowa DOT Project Concept Team decided to perform the second-stage ABC Analytical Hierarchy Process (AHP) to further validate the consideration of ABC for the project. The AHP is a pairwise comparison tool that can be used to perform a qualitative analysis between two choices. In this case the choice is between using ABC methods and traditional construction methods for the bridge replacement project. There are five main categories that are evaluated when making the comparison between the two alternatives. The main categories are direct costs, indirect costs, schedule constraints, site constraints and customer service. The main categories are further broken into sub categories, for example direct costs sub categories include: construction costs, maintenance of traffic costs, Right-of-Way (ROW) costs, design costs, etc. The sub categories

are ranked in terms of importance by the Project Concept Team and then the two alternatives are scored at how they best satisfy each category. Once the AHP was completed for the US 52 over Mississippi River Overflow bridge replacement the ABC method scored 0.72 while the traditional construction method scored 0.28 indicating somewhat strongly that the ABC method was the preferred alternative.

ABC has five different tiers as defined by Culmo (5). The tiers correspond to the transportation network mobility impact time due to construction activities.

- Tier 1: Traffic Impacts within 1 to 24 hours
- Tier 2: Traffic Impacts within 3 days
- Tier 3: Traffic Impacts within 2 weeks
- Tier 4: Traffic Impacts within 3 months
- Tier 5: Overall project schedule is significantly reduced by months to years

The Iowa DOT ABC Policy does not delve deeply into how to select the ABC tier for a project. The ABC tier is developed by the Project Concept Team and then the ABC design is developed based on the desired schedule.

It may be feasible to make nearly every ABC project into a tier 1 project at great effort and expense but that is not a realistic or practical way for a transportation network owner to administer the network. The owner has to make a decision on how best to allocate resources, minimize hardship for the transportation network users and maintain the network with a finite budget. In the case of the US 52 over Mississippi River Overflow Bridge replacement project, closing the road for bridge construction creates a significant and obvious hardship for the users of that route given the long detour. However, the route is not a heavily traveled route indicated by the low AADT of 2300. Selecting the appropriate tier becomes a balancing act of costs and benefits.

One of the first things the Project Concept Team will evaluate is user costs. The daily road user costs are calculated by the Iowa DOT using a formula that takes into account AADT, Average Daily Truck Traffic (ADTT) and length of detour out of distance travel. The typical formula assumes that 50% of roadway users will find an alternate route, cancel or postpone their trip. For the Sabula Mississippi River Overflow Bridge replacement project the 50% factor may be too low because there are no nearby alternate routes to cross the Mississippi. A factor of 80% may be more appropriate assuming 20% of the roadway users can cancel or postpone their trip until the end of the construction.

$$\text{Daily Road User Cost} = 0.5 * [(AADT + 2 * ADTT) * \text{Miles out of distance} * \$0.375]$$

The calculated daily road user cost for this project is \$17,700 per day using the typical formula. For traditional construction with an estimated closure of 200 calendar days that is a total road user cost of \$3,540,000. For the ABC period selected with a critical closure of 4 to 6 weeks the road user cost is \$743,400 assuming the contractor uses all 6 weeks. The critical closure is defined as the time the roadway is closed to traffic for bridge replacement. Construction activity that does not require roadway closure will occur before after the critical closure but not be counted towards the allotted critical closure time period. Spending additional funds to accelerate the construction is clearly a benefit for the Iowa DOT's customers. Construction cost estimates for the ABC alternative are about \$1,500,000 more than the traditional construction alternative. The Iowa DOT must weigh this additional ABC cost very carefully because of the finite budget for

maintaining Iowa's transportation infrastructure. While our transportation customers are realizing a theoretical savings of \$2,796,600 in user costs the additional ABC cost of \$1,500,000 is absorbed in the department's highway improvement program. The DOT's management ultimately decided that the solution in between tier 3 and tier 4 best suited the transportation customer's needs balanced with the DOT's financial position in the highway improvement program.

ABC DESIGN DETAILS

Once the desired ABC schedule was established it was the bridge designer's responsibility to develop a design in which the DOT confident of being constructed on or ahead of schedule. For the Mississippi River Overflow Bridge the substructure is the biggest challenge. Spanning the entire overflow of 376' was cost prohibitive so this meant that some substructure has to be constructed in the overflow channel. The Mississippi River water surface profile is regulated by an extensive lock and dam system which means the overflow is typically full of water to a depth of approximately 15 feet. In addition, there is a large scour hole adjacent to the existing bridge with an estimated depth of over 30 feet. There have been some attempts at scour mitigation by dumping large revetment about 1.5 foot diameter up to 4 foot diameter around the existing piers which further complicates the construction of the new substructure.

The design team selected a drilled shaft straddle bent foundation for the three bents in the overflow channel. The intent is to construct the drilled shaft foundation prior to the critical closure when the roadway is closed and traffic is detoured. Revetment will need to be removed in selected areas in order for drilled shaft installation. Once the contractor has constructed the drilled shafts to get up out of the river the critical closure can start by closing the roadway and commencing on the existing bridge demolition.

For the remaining substructure elements the design team has been weighing the options of precast concrete straddle bent caps versus cast-in-place straddle bent caps. The most likely outcome will be that a design alternate is shown in the plans allowing the contractor to select the design that best suits his/her capabilities. The primary benefits of the precast concrete straddle bent caps are the speed of construction using grouted splice couplers to connect the cap to the columns. Concerns with the use of a precast cap are the pick weights of the elements, installation tolerance to make the column to cap connections and the congestion in the connection area as there is a significant moment capacity to be developed at that location. The benefits of the cast-in-place straddle bent caps are that the connection congestion is alleviated as the grouted splice couplers will not be necessary. There is a significant reduction in risk of fit-up as the reinforcing can easily be adjusted to accommodate construction tolerances and inaccuracies. The primary negative factor with a cast-in-place straddle bent cap is time on the critical path of construction. The duration of the desired critical closure makes the cast-in-place option feasible with advance planning and preparation so it is likely both the cast-in-place and precast option will be carried forward in the final design for letting.

The abutment foundations will be supported on driven steel H-piling. With the work on the straddle bent piers in the river on the critical path for construction, there will be a small amount of float in the schedule for abutment construction. The design advanced for this will be a standard cast-in-place footing since the construction should not be on the critical path.

The bridge superstructure will utilize standard pretensioned prestressed concrete beams. Occasionally the suggestion is brought up to accelerate bridge deck construction through the use of stay-in-place steel decking. The Iowa DOT has a longstanding policy of not permitting stay-in-place steel decking due to the desire to thoroughly inspect bridge deck condition both from the top of the bridge and underneath the deck. Steel stay-in-place decking has been thought to obstruct the inspection of the concrete deck condition. The Iowa DOT has utilized precast prestressed deck panels as stay-in-place forms. Criteria are established in the Iowa DOT LRFD Bridge Design Manual (4) on when these prestressed deck panels may be used and those criteria include the following:

- The bridge is constructed with pretensioned prestressed concrete beams.
- The intermediate diaphragms are steel.
- Skew is 45 degrees or less.
- The bridge is on a rural highway with traffic volume AADT of less than 3000 VPD.
- The bridge is not being built by staged construction.

The Sabula Mississippi River overflow bridge meets all the Iowa DOT criteria for the use of prestressed deck panels and so the prestressed deck panels will be specified on the project. The plan is detailed in such a way that the prestressed deck panels are an alternate and the contractor could choose to use a conventional full depth cast-in-place deck.

A draft Gantt chart schedule has been developed by the design team and is shown in Figure 2 – Draft ABC Schedule.

Task	Days	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Remove Existing Bridge	5	■	■	■			
Abutment Pile Driving	2	■	■				
Abutment Construction	4	■	■	■	■		
Pier Construction	12	■	■	■	■	■	■
Set PPC Beams	4			■	■	■	■
Precast Deck Panels & Forming	7			■	■	■	■
Deck Reinforcing	7			■	■	■	■
Place Deck	4				■	■	■
Approach Paving	3					■	■
Concrete Barrier Rail	4					■	■
Guardrail	3						■
Longitudinal Grooving	1						■
Pavement Markings	1						■

Figure 2 – Draft ABC Schedule

An Incentive/Disincentive (I/D) contract is anticipated to be used. The critical closure will be set at 42 days with the contractor able to earn an incentive for each day the critical closure is shortened. There will be a cap on the incentive of 14 days. The disincentive the contractor pays if the critical closure exceeds 42 days does not have a cap. The critical closure is defined as the time period the roadway is out of service for bridge replacement. Work outside of the critical closure will utilize a standard working day contract.

The ABC design details shown in the plans have been developed to allow the bridge contractor some flexibility through the use of alternates. The design is anticipated to enable the typical contractor bidding on bridge work in Iowa to successfully complete the project on or before the desired maximum six week critical closure.

CONSTRUCTABILITY REVIEW

The State of Iowa requires that the Iowa DOT utilizes a design-bid-build process which is an additional challenge to implementation of ABC projects. Accelerating bridge construction generally involves impacts to the bridge contractors means and methods of construction. In a design-build type contract the design engineer can tailor the design to specifically accommodate the means and methods of the contractor he or she is directly working with. In the design-bid-build environment the engineer must prepare a design that can be reasonably constructed by many different contractors who are potential bidders on the project. Collaborating directly with one contractor prior to letting is not permitted by the design-bid-build process. However, on ABC projects contractor feedback is critical to developing a design that will enable the contractor to complete the construction in the desired critical closure timeframe.

The Iowa DOT has tackled this problem of obtaining feedback while avoiding tailoring a design to one specific contractor by partnering with Associated General Contractors (AGC) of Iowa to obtain feedback from a multitude of contractors without singling out any one specific contractor. A design constructability review will be held with the AGC of Iowa when the plans have been developed to an approximately 60 to 90 percent level of final detail. The meeting minutes will be summarized and publicly available. Design changes that are made based on AGC of Iowa contractor feedback are documented.

Additionally, for this project the Iowa DOT has hired Parsons Corporation to provide design and constructability checks of the project. Parsons Corporation has bridge design services and has a heavy civil construction division that can evaluate the draft Gantt chart schedule and provide input on construction feasibility. Parsons' heavy civil construction division is not an eligible bidder for this bridge replacement work and serves as an independent analysis. Design changes made based on feedback from Parsons will be made ahead of the constructability review by AGC of Iowa.

CONCLUSION

The Sabula Mississippi River Overflow Bridge replacement project is an opportunity for the Iowa DOT to use ABC techniques to serve our transportation network users with good customer service. The ABC mobility impact tier chosen is a DOT management balancing act to minimize the hardship presented by the temporary elimination of this transportation link and optimize the use of the Iowa DOT's financial resources for maintaining the transportation network. The Sabula Mississippi River Overflow Bridge design is the next in a series of ABC projects that are moving the Iowa DOT from an ABC demonstration phase to a full ABC implementation phase. While not every new bridge or bridge replacement project will be picked to utilize ABC techniques, the frequency of ABC projects is increasing. Collaborating with contractors is a key to successfully implementing ABC and the Iowa DOT has a framework for collaborating in the design-bid-build environment that has proven to be a successful approach.

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NOTATION

AADT – Average Annual Daily Traffic
ABC – Accelerated Bridge Construction
AGC – Associated General Contractors
AHP – Analytical Hierarchy Process
DOT – Department of Transportation
ROW – Right of Way
SIBC – Slide-In Bridge Construction
VPD – Vehicles Per Day

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