IN THE EYE OF THE STORM: UTILIZING PRECAST SOLUTIONS TO ACCELERATE BRIDGE CONSTRUCTION

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ABSTRACT

The perfect storm…a challenging economy with shrinking budgets…a project requiring minimal construction time…a high profile project location. This combination is creating challenges for many transportation projects. However, Accelerated Bridge Construction (ABC) techniques in combination with utilizing precast concrete structural elements can provide a solution to these transportation infrastructure challenges. The replacement of the 41st Street Bridge over the Big Sioux River in Sioux Falls, South Dakota fell into this category. Originally designed under a contract with the US Army Corps of Engineers as an element of a flood control project, the City of Sioux Falls decided to accelerate the replacement of this bridge due to concerns with prolonged traffic restrictions on this critical arterial. Consequently, the bridge was redesigned from a steel superstructure to a precast/prestressed, side by side concrete box superstructure.

Located on the busiest street in the state of South Dakota, the bridge is integral to the community's transportation network. This paper will highlight the structure alternatives investigated, the collaboration efforts among all stakeholders to meet the client's goal, the innovative bid method and how the selected precast side by side box girder concrete bridge superstructure enabled the City to calm the storm and successfully navigate the project life cycle.

Keywords: Accelerated Construction, Construction, Creative/Innovative Solutions and Structures

INTRODUCTION – PROJECT INCEPTION

Fig. 1: Project Location Map

The 41st Street Bridge over the Big Sioux River in Sioux Falls, South Dakota is located on one of South Dakota's busiest streets. As shown in Figure 1, the bridge is situated in an established business district and the bridge serves as a vital link, connecting citizens with area businesses and providing a necessary commuter route. The bridge was originally scheduled to be replaced under a design contract with the US Army Corps of Engineers (USACE) as an element of a flood control project for the purpose of improving levee safety along the Big Sioux River. The flood control project was needed to provide protection for existing homes and businesses in Sioux Falls by raising the levees.

Under a separate contract with the USACE, HDR had previously performed design services to replace the existing bridge. The bridge plans had been carried out to the 90% stage pending final funding for the project. The previous bridge design consisted of 2 lanes northbound, 2 lanes southbound and 5' sidewalks on each side separated by traffic barriers. The previous design utilized a 3-span (97'-6", 110'-0", 94'-6"), rolled steel beam superstructure, a cast in place concrete deck, wall type piers and integral abutments constructed in two major stages as shown in Figure 2.

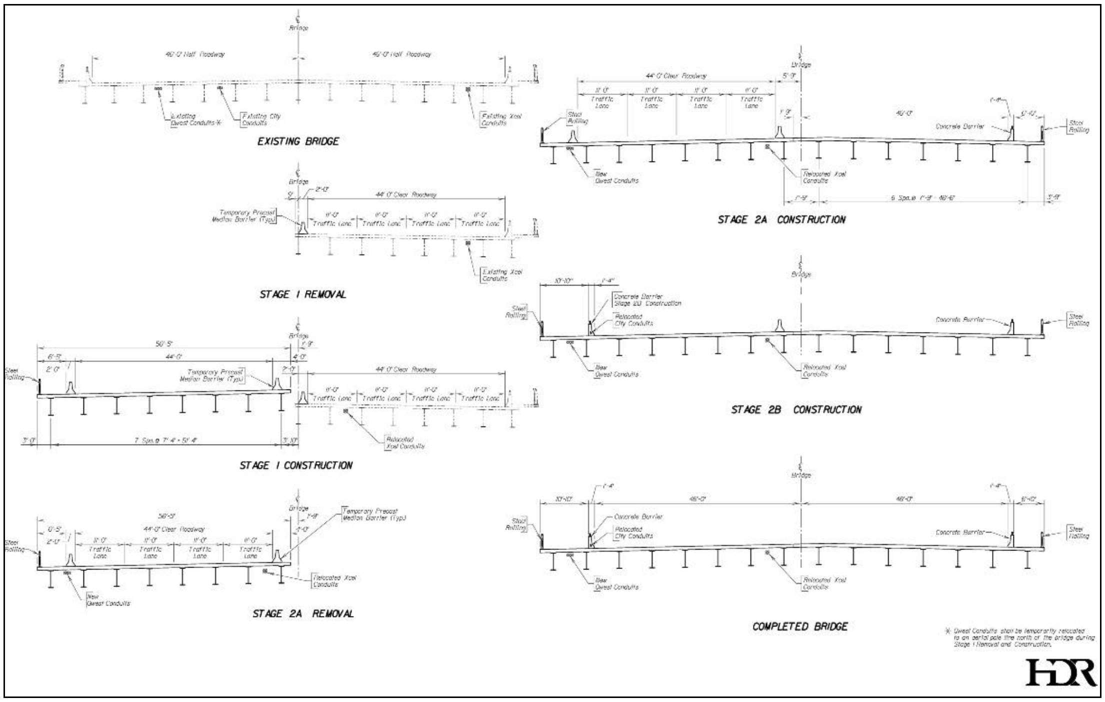

Fig. 2: Previous Design Staging Plan (shown for general construction staging)

The construction for this original design, utilizing conventional construction techniques, was estimated to take one year to construct due to the staging conditions, the USACE’s levee project and the myriad of utility relocations required for construction for the new bridge. Because of the condition of the existing bridge and scheduling issues with the USACE’s levee project, the City of Sioux Falls decided to replace the bridge ahead of the levee project. In addition, due to the high traffic volume and importance to nearby businesses and commuters, the City desired to significantly reduce the construction duration from the original schedule. To achieve that, the City contracted with HDR to conduct an alternatives study to identify potential structure alternatives and construction techniques to significantly reduce the construction duration at a reasonable cost while providing a bridge that would service its citizens for a long time.

The selected bridge alternative consisted of a 3-span (90’-0”, 125’-0”, 87’-0”), side-by-side precast/prestressed concrete box girder bridge with a 5 inch CIP deck, pile encased bents and integral abutments. The bridge would be constructed in two stages, maintaining four lanes of traffic at all times. The bridge was a part of a larger infrastructure project that was bid on January 17, 2010 and construction of the bridge concluded with all lanes open to traffic on July 25, 2010. The winning bid assumed 140 days to complete the bridge construction, a time savings of over 60% from the original schedule and a cost savings of 15% from the engineer’s estimate when considering full incentive payment. The actual construction duration was 113 days, resulting in an actual time savings of almost 70% from the original schedule. Each stage of construction maintained a minimum of four lanes of traffic, preserving the access for area businesses and minimizing impact on commuters. The final product meets the needs of the owner, accommodates flood control requirements and provides a bridge that will service the citizens of Sioux Falls well into the future.

The remainder of this paper will discuss the planning phase and collaboration efforts that led to the recommended bridge type and configuration, final design details and the innovative bid methods that met this goal. Specifically, the paper will focus on the bridge alternatives studied, the involvement of stakeholders throughout the project to meet the owner's needs, the use of incentives to realize both cost and time savings on the project and the implementation of the latest research for final design.

Fig. 3: Existing Bridge

Fig. 4: Proposed Bridge Rendering

Fig. 5: Photo Completed Bridge

PRELIMINARY STUDY

The primary goal of the preliminary bridge alternatives study was to identify and evaluate available construction alternatives and methods to accelerate the replacement of the existing bridge while minimizing impact to traffic and nearby businesses. Initially, a kick off meeting was held between HDR and the City of Sioux Falls to discuss potential structure alternatives, possible traffic impacts and accelerated construction materials and construction techniques. The following sections discuss the process and the results of these studies.

STRUCTURE ALTERNATIVES

The Bridge Alternatives Study consisted of evaluating the following structural systems utilizing accelerated construction materials and accelerated techniques:

- Adjacent precast/prestressed concrete box girders
- Precast/prestressed concrete I-girders
- Precast/prestressed Inverted “T” beams
- Full depth/full width precast deck panels
- Precast concrete substructures
- Steel rolled beams
- Roll-in, Roll-out construction
- Drilled shaft foundations

The original design was also investigated for ways to accelerate its construction. The original design utilized wall piers on a conventional footing with steel piling. These piers were to be located over the existing pile cap locations. Consequently, during the study, it was determined that the pier removals were on the project critical path. It became evident that time savings would be realized if pier removals were not on the critical path. Therefore, HDR decided to make the middle span longer to minimize conflict between proposed and existing substructure elements. This would allow the contractor to potentially begin construction of the new piers prior to removal of the existing piers.

Additionally, the construction of the piers and pier cofferdams was also on the critical construction path. Therefore, the project team looked into ways to minimize these impacts on the construction schedule. Investigated options included eliminating the footing, utilizing precast concrete substructure elements and minimizing the contractor’s substructure construction time in wet conditions. By eliminating the conventional footing, one step was removed from the construction of the pier, thereby, reducing the overall construction duration and minimizing the contractor’s time in the river. Utilizing precast substructure elements can be a very efficient construction technique when there are multiple pier elements of the same size and shape on a project. There are two pile encased wall piers on the project and the width of the wall piers is approximately 120 feet, thus requiring multiple precast elements per pier. The project team concluded that the minimal time savings potentially realized, combined with the potential contractor’s learning curve for constructing precast substructure elements did not warrant the use of this acceleration option.

The final item investigated to accelerate construction included minimizing the contractor's time in the river. During the investigation, the project team learned that the City could control the amount of water in the channel by diverting the flow at an upstream location from the bridge. Although the contractor would be assuming some risk during construction, this would allow the contractor to construct the new pier in the dry, potentially eliminating the need for a cofferdam. Taking into account regional contractor capabilities, site considerations and the design modifications discussed above, the alternatives shown in Table 1 were carried through for further investigation. For each of the alternatives, a cost estimate and schedule were developed based on closing the existing bridge and constructing the new bridge in the clear or constructing the new bridge in stages while maintaining four lanes of traffic.

Table 1: Bridge Construction Acceleration Alternatives

<table>
<tr><th colspan="4">Alternative</th><th>Description</th></tr>
<tr><td></td><td colspan="2">1
Baseline</td><td>-Standard Construction
-CIP Deck
-Steel Rolled Beams</td><td>This was the baseline option utilizing standard construction methods and materials. This option utilized the original design with rolled steel beams, cast-in-place concrete deck (with removable forms) and cast-in-place substructure on driven steel piling.</td></tr>
<tr><td rowspan="4">Closed To Traffic – Accelerated Construction</td><td colspan="2">2A</td><td>-P/S Concrete Girders
-CIP Deck</td><td>This option utilizes a cast-in-place concrete deck (with removable forms), precast/prestressed (P/S) concrete I-girders and cast-in-place substructure on driven steel piling.</td></tr>
<tr><td colspan="2">2B</td><td>-Welded Plate Girder (WPG)
-Full Depth Precast Deck Panels</td><td>This option utilizes full depth precast deck panels, welded steel plate girders and cast-in-place substructure on driven steel piling.</td></tr>
<tr><td rowspan="2">2C</td><td>w/ piles</td><td>-P/S Concrete Box Girders
-CIP Deck
-Driven Steel Piling</td><td>This option utilizes a cast-in-place concrete deck, precast/prestressed concrete box girders and cast-in-place substructure on driven steel piling.</td></tr>
<tr><td>w/ shafts</td><td>-P/S Concrete Box Girders
-CIP Deck
-Drilled Shafts at Piers</td><td>This option utilizes a cast-in-place concrete deck, precast/prestressed concrete box girders, cast-in-place substructure with a drilled shaft foundation at the piers and driven steel piling at the abutments.</td></tr>
<tr><td rowspan="4">Staged Construction w/ Traffic Maintained – Accelerated Construction</td><td colspan="2">3A</td><td>-P/S Concrete Girders
-CIP Deck</td><td>This option utilizes a cast-in-place concrete deck (with removable forms), precast/prestressed concrete I-girders and cast-in-place substructure on driven steel piling.</td></tr>
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UTILITY STAGING

The existing design required that several utilities attached to the existing bridge be relocated during the bridge construction. Utility relocations would be time consuming and were a big factor in the construction duration. Therefore, during the investigation process, the project team identified the importance of relocating all utilities from the existing bridge prior to commencing bridge construction. This step would help to reduce the construction duration risk of the contractor and, therefore, facilitate the accelerated construction activities. Discussions with utility companies began immediately and concurrence was obtained to temporarily relocate the utilities off the bridge. However, the final relocation had to wait until the final bridge type and construction methods were determined.

COST ESTIMATE & SCHEDULING

A detailed cost estimate for each option was prepared based on the estimated quantities for the bridge items. Contingency costs, costs of engineering services and incentive costs were added to the construction costs and varied based on the option investigated. Costs were developed using two different approaches. The first approach made use of industry accepted software, Heavy Bid from HCSS. The second approach used available historic unit price data from South Dakota's Department of Transportation and applied those prices to the same preliminary quantities. A summary of the cost estimates for each of the alternatives investigated is shown in Figure 6.

Additionally, the project team developed critical path schedules for each alternative. The program SureTrak, a Primavera product, was used to develop the timelines for each alternative. Schedules were then adjusted based on input from contractors. As mentioned previously, the following critical path items had a large impact on the length of schedule required for each option:

- Demolition of the existing bridge piers
- Constructing the new piers – including potential cofferdam installation
- Forming and pouring the new bridge deck

Options 2C and 3C (precast/prestressed concrete box beams) with drilled shafts showed the shortest duration. This was due to elimination of the existing pier removals from the critical path, eliminating the possible need for cofferdams for pier construction and substantially reducing the need to form the deck slab. Options 2B and 3B utilized full depth precast deck panels in lieu of the traditional cast in place deck. This reduced the construction time by at least one calendar month when compared to the baseline option (the original modified design). In general, options that utilize precast/prestressed concrete girders with a cast-in-place deck will require less time for construction than cast in place deck options with steel girders. A summary of the preliminary construction durations developed for each of the options is shown in Figure 6. It is worthwhile to note that the use of stay-in-place forms were not to be considered for the construction of the new bridge due to current South Dakota DOT policies.

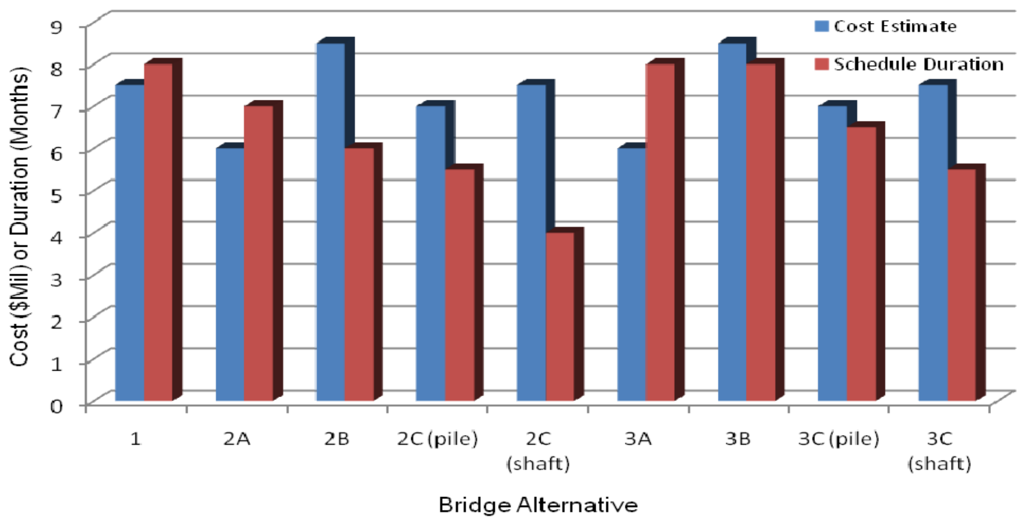

Fig. 6: Comparison of Preliminary Cost Estimates and Schedule Duration

COLLABORATION

During the study phase, dialogue between all stakeholders was essential to the process. The project team coordinated with the City of Sioux Falls, area businesses, the general public, contractors and fabricators to solicit input and to help narrow the alternatives and produce the desired outcome for the owner. The following paragraphs briefly discuss the collaboration between each of the stakeholders. After the conclusion of the investigation, it was very evident that the overall collaboration between all stakeholders driven by the project team helped the City in terms of costs, schedule, relationships and public perception.

Contractor's Perspective

The project team used contractors as a sounding board during the preliminary phase. Once the preliminary cost estimates and schedules were developed for each alternative, the team held one-on-one meetings with area contractors to get feedback on the specifics of each cost estimate and schedule. Prior to each meeting with a contractor, the project team provided a set of sketches showing each alternative structure type so that the contractor could develop their own timeline for each alternate. During the meetings, a comparison was made between the design team's schedule and the contractor's schedule. This activity proved beneficial as it allowed the team to refine its preliminary efforts and provide the City of Sioux Falls with more accurate assessments of cost and schedule. Because of previous relationships built with the local contractors, the design team was able to work closely with the contractors during this investigation phase of the project.

Additionally, the contractors discussed means and methods that would potentially be utilized on the project if they won the bid. This allowed the project team to get an important view of how a contractor might construct the bridge for each of the potential alternatives.

Once the project was awarded, the project team interviewed the contractor who won the bid. This discussion provided important feedback and gave the project team a snapshot of the contractor's thoughts at the bidding of the project, a few months prior to commencing construction. The contractor stated that the incentive utilized in the innovative bid method (see the BID METHOD section below) created interest from their organization. They would not have otherwise bid on the job if the incentive was not part of the contract as the project location is on the edge of the maximum distance they would typically travel for a project.

According to Robert Cramer of Cramer & Associates, the contractor that won the bid, there were multiple features of the design that would help to accelerate the construction schedule. These features included the side by side precast/prestressed concrete box beams which allowed the contractor to minimize the amount of formwork required for deck construction. Furthermore, the contractor potentially had an advantage over other local contractors because they had experience with accelerated construction techniques. Having finished a job shortly before this project that involved acceleration techniques, he felt his team was adequately prepared to bypass the learning curve and hit the ground running. Additionally, the contractor was experienced with box girders, had the capability to lift these larger box girders and had experience with grouting techniques for the shear keys. The decision to lengthen the middle span combined with the elimination of the pier footings also helped with acceleration according to the contractor. This allowed for construction of the pier to begin prior to the completion of the existing pier removal. All of these features allowed the contractor to win the job with a bid of 140 days, 20 days less than each of the other five bidders.

As a lessons learned comment, the winning contractor also mentioned that one potential way to further accelerate the construction would have been to utilize a precast overhang at the exterior box girders. In their investigation, the contractor concluded that adding a precast overhang would probably not be a cost savings for this specific job, but it would have helped to decrease the overall project duration.

Public Involvement

The City of Sioux Falls, assisted by HDR, met individually with all landowners located within the proposed traffic control limits of the project. The purpose of the meetings was to inform the affected landowners of the bridge replacement study including the proposed construction phasing and the direct impacts the project would have to their property. Also presented to the landowners/business owners during the individual meetings were the contracting methods and bridge materials/methods being studied for the purpose of accelerating the construction.

The project team developed an extensive public outreach component for this project. This included meeting with private business owners, hosting public information meetings and establishing an informational website to disseminate information to interested parties. Additional efforts included offering a project hotline number to report issues, hosting regular informational meetings on local public television, publishing weekly newsletters during construction and maintaining two separate webcams throughout the duration of the project.

Consequently, there was not one complaint during the construction of the bridge by businesses or citizens and, interestingly, one directly affected business in particular saw sales increase during the construction period as a result of the construction activity and interested onlookers.

Fabricators Input

Because precast/prestressed concrete box beams had not been used in this area prior to this investigation, the project team contacted fabricators outside the project area to research potential fabrication schedules, delivery logistics and costs. The box girder fabricator that the project team coordinated with during the study was from Colorado and provided good insight into costs for producing the boxes, shipping the boxes, production rates for setting the boxes and turn around time for fabricating each beam. Consequently, the team was able to provide reasonable estimates of costs and time for construction of the applicable alternatives.

Furthermore, Gage Brothers, a local, Sioux Falls precaster that won the bid to fabricate the box girders, gave the project team good insight into the process their organization undertook in order to bid on this job, even though they had not produced box girders prior to this project and had initially opposed the box girder concept. The fabricator was hesitant to bid on this job due to the perceived steep learning curve and the thought that it would prove to be a more expensive option because of the difference in material between a box girder and an I-girder, which they were very familiar with. However, the fabricator talked with other fabricators from outside their competitive circle and actually made a visit to a fabricator's plant to see how they produced box girders. From this visit, the fabricator gained valuable insight into fabrication methods and costs for fabrication. Additionally, the fabricator was able to modify an existing set of forms they already owned so that they would not have to purchase new forms for this job. Not only did this save the fabricator money, but they were able to pass this savings on to the City and minimize the cost of construction.

FINAL DESIGN FEATURES

The selected bridge replacement alternative utilized staged construction as a result of a traffic study performed by HDR. The study was performed concurrent with the structure investigation to determine the impacts of closing the 41st Street Bridge for the duration of construction versus the impacts of staging the construction of the bridge and maintaining two lanes of traffic in each direction during construction. The traffic study showed that the option of closing the bridge would require many upgrades to the existing streets to improve operations including adjustments to many nearby signalized intersections. Due to these traffic impacts, it was determined that it would be more advantageous to construct the bridge in stages. Figure 7 is of the typical cross section of the new bridge and Figure 8 shows the plan and elevation sheet.

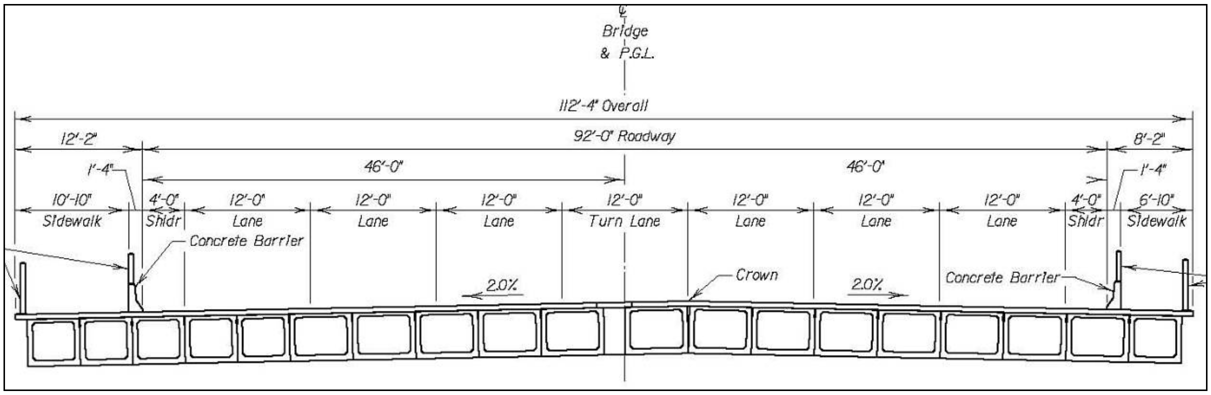

Fig. 7: Typical Section of Bridge

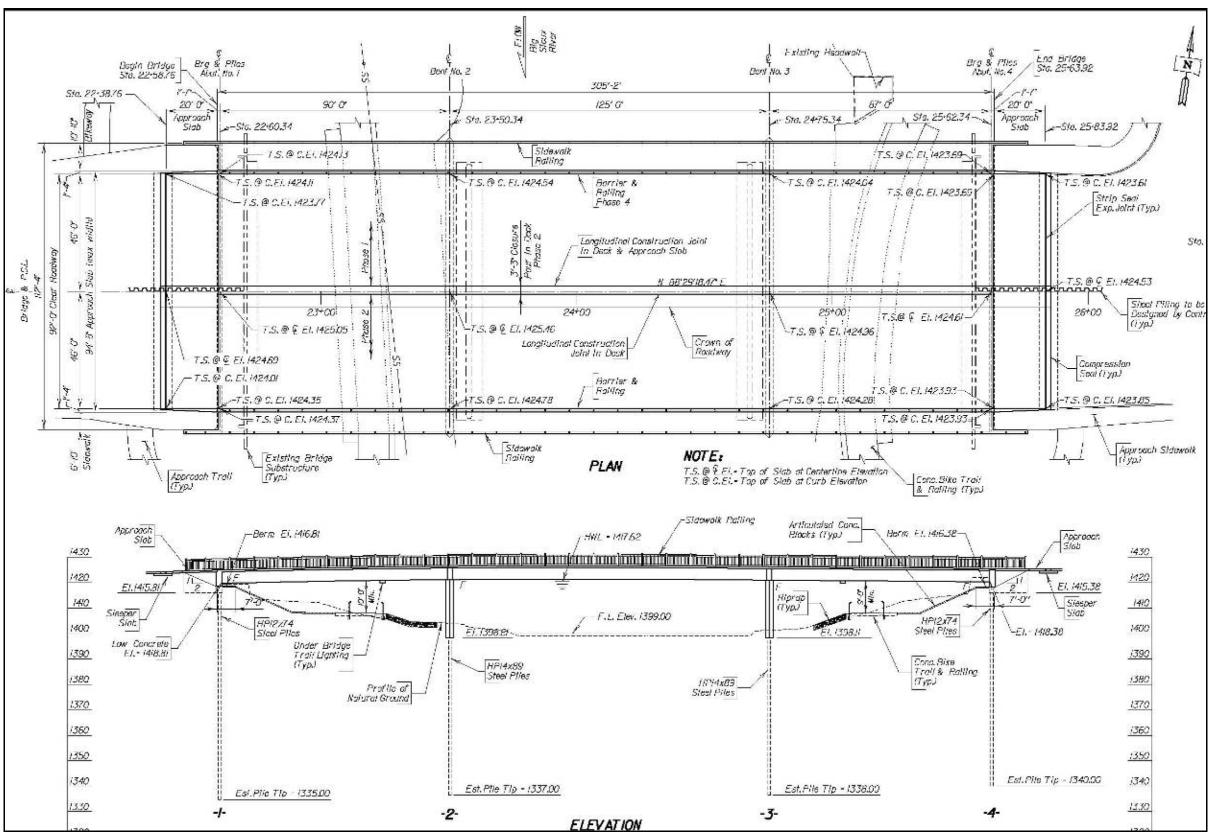

Fig. 8: 41st Street Bridge Plan and Elevation

The overall features of the replacement bridge were:

- Three-span continuous concrete box girder bridge with a span arrangement of 90'-125'-87'. Integral abutments and a continuous superstructure over the interior piers.
- Total width of bridge is 112'-4" carrying 7 lanes of traffic, 4' shoulders and a sidewalk on each side of the bridge. Overall length of bridge is 305 feet.
- No skewed substructure.
- Built using staged construction maintaining two lanes of traffic in each direction with 11'-0" wide lanes.
- The design and bridge layout utilized two different beam widths to satisfy staged construction.
- No deck drains were required due to the longitudinal grade of the bridge and the shoulder width.
- Steel H-pile concrete encased wall piers.
- Subsurface bearing Strata consisted of dense quartzite sand overlain with stiff fat clay and lean clay and silt.

To help improve the overall service life of bridges of this type, the design team incorporated details accounted for the latest in research recommendations for side-by-side precast/prestressed concrete box girders. However, a recurring problem has been longitudinal cracking at the grouted keyway between adjacent box girders. This could lead to reflective cracking in the concrete deck, which allows chloride-laden water to penetrate the sides and bottoms of the concrete girders causing corrosion of the steel reinforcement in the girders. Generally, these types of bridges perform well otherwise and to address this potential reflective cracking problem, the design team reviewed the latest research literature and also reviewed details for this type of bridge from several other State DOT's including Colorado, Illinois and Oregon. The design team studied the use of AASTHTO standard box girders from the afore-mentioned DOTS. The design team ultimately decided to use the Colorado DOT standard box girder due to its ability to handle the span lengths for this bridge. The concrete girders selected for final design were 4'-6" deep and 5 foot and 6 foot wide. The girder and superstructure design included the following design features:

- The design followed recommendations from NCHRP Report 393 for transverse post-tensioning.
- Transverse tie-rods were used to post-tension the box girders together. The keyways were filled with grout after all tie-rods were tensioned for a pair of adjacent girders. The minimum post-tension force and tie-rod capacity were set to insure a minimum compressive stresses between the boxes without exceeding the tie-rod capacity at the maximum transverse expansion of the superstructure. For a relatively wide bridge, such as this, thermal expansion and contraction impacts on tie-rods forces and minimum compressive stresses were of critical importance for good performance.
- The design plans required the girder keyways to be sandblasted prior to shipping to provide a better bonding surface for the grout and the keyways were kept moist for 24 hours prior to placing grout. The non-shrink grout was to be water cured for a

minimum of 72 hours in an attempt to reduce shrinkage stresses and ensure proper strength development of 4000 psi.

- Precast girders utilized a final concrete strength of 8,000 psi and concrete release strength of 6,000 psi.
- Low-lax, Grade 270, seven-wire, 0.6” diameter prestressing strands was used.
- Due to the transverse post-tensioning, the differential camber between the girders had to be addressed for the P/T rods to fit thru the transverse tie-rod ducts. Provisions were provided in the plans to cast all girders for a particular span within a certain number of days so all girders would be cambered at the same rate. The fabricator submitted an alternate girder casting plan based upon girder length and bed setup and their coordination with the contractor on the overall project schedule.
- The design criteria for the girders required minimum prestressing steel for positive camber at release and final.

This bridge type was unique to the State of South Dakota and to some of the local precast fabricators. Other design aspects of the bridge include:

- Bridge design utilized the 3rd Edition of AASHTO LRFD Bridge Design Specification.
- A concrete full depth closure-pour was used between the stages of construction.
- A 5.5” thick cast-in-place composite deck with a concrete strength of 4500 psi was used. The deck was required to be cured per special provisions to reduce the potential for shrinkage cracking and to provide a durable driving surface.
- The plans called for a skipped deck pour sequence. Ultimately, the contractor was allowed to pour the deck end to end with no transverse joints in the deck since they were able to meet the minimum pour rate of 40 cubic yards per hour using a set retarder.
- Abutments and interior piers were designed using a single row of 14x89 H-piles. This pile size was required to resist the superstructure load combined with the ice load.

BID METHOD

Multiple bidding methods were discussed with the City of Sioux Falls during the preliminary phase of the project. These methods included utilizing an A+B bid structure, incorporating incentive/disincentive options in the contract and design/build options. In preliminary discussions with area contractors, the A+B bidding method was a method that contractors thought could provide the City more flexibility because they could set a maximum number of days allowed for construction and set a cap for any incentives utilized on the project.

The final bid structure used an A+B bid along with an incentive/disincentive dollar value per day. The City specified a maximum of 160 days for each bid. User costs were calculated for both a staged construction schedule and a total closure construction schedule. However, since the detour route was not overly long, the user costs did not reflect the importance of the

41st Street corridor. Therefore, it was decided that a percentage of the estimated construction cost of the project would better serve the City and it was decided to use 5% to 6% of the estimated cost as an incentive pay for the project. It was agreed that a total incentive of $500,000 would entice contractors to both bid the project and use all available resources to meet the schedule. It was also decided that since the allowable contract days would be accelerated, the contractor should receive a portion of the incentive in a lump sum payment. Therefore, there was a $250,000 incentive captured by the contractor if the project was completed in the days bid (140 days). For each additional day that the project would be completed before the number of bid days, there was an additional $10,000 incentive up to a maximum total incentive of $500,000 for the project.

From conversations with the winning contractor, this bidding structure played a large role in their organization bidding on this job. Consequently, by utilizing A+B bidding and combining this with incentives, the City was able to save time and money. Furthermore, the winning bid came from a contractor that would not have been bidding on this job otherwise.

The final bid for the winning contractor came in at $4.4 Million for the bridge ($127/sq. ft.) and 140 days (20 days less than the contract requirement of 160 days). The actual construction duration was 113 days, allowing the contractor to realize the full $500,000 incentive.

CONCLUSIONS

The end goal of this project was to accelerate the construction of the 41st Street Bridge at a reasonable cost while providing a bridge that would service the citizens of Sioux Falls well into the future. Collaboration among the designer, the owner, the public, contractors and fabricators was essential to accelerating this project and providing value to the City of Sioux Falls. Additionally, implementing the latest research in the use of precast/prestressed side-by-side concrete box beams allowed for further acceleration of the construction of the 41st Street Bridge. The winning contractor completed the bridge construction in 113 days, a reduction of almost 70% from the originally proposed schedule utilizing conventional construction techniques with a rolled steel beam superstructure. Furthermore, the innovative A+B bidding structure along with the incentives pulled in bids from contractors that would not have bid this job otherwise. As a result, the City was able to realize a minimal cost and schedule combination and now has a new, state of the art bridge to service it’s citizens needs on one of the state’s busiest streets.