Accelerated Design and Construction for the 24th Street Bridge in Council Bluffs, Iowa

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ABSTRACT

With the help of Highways for Life initiative and the Innovative Bridge Research and Construction program, Iowa Department of Transportation (Iowa DOT) is getting the opportunity to use proven innovations to meet the needs of the traveling public during and after construction of the 24th Street Bridge in Council Bluffs, Iowa. Specifically, construction acceleration, durable high-performance materials, innovative contracting methods, intelligent transportation systems, and a health monitoring system are some of the innovations being used.

The 24th Street Bridge over I-80/I-29 in Council Bluffs, Iowa, will feature full-depth post-tensioned concrete deck panels supported on high-performance steel girders. The two-span steel bridge will serve as the primary access to some of the most popular attractions in Western Iowa and will highlight the aesthetic theme for the I-80/I-29 corridor.

This paper focuses on the innovations associated with the design, fabrication, and construction of the 354 ft. by 82 ft. steel bridge. The information presented is of use to bridge owners, designers, and other industry professionals as they strive to make the best use of high-performance materials and the latest construction innovations.

Key words: accelerated construction—precast concrete decks
BACKGROUND

Lower revenues and higher costs of construction projects have had a dramatic impact on the transportation infrastructure budget across the nation. Thus, it is important for state departments of transportation to use cost-effective and economically sound methods in dealing with the aging infrastructure that is in dire need of rehabilitation.

The Highways for Life (HfL) initiative and the Innovative Bridge Research and Deployment (IBRD) program is giving the Iowa Department of Transportation (Iowa DOT) the opportunity to use proven innovations that are new to Iowa to meet the needs of the traveling public. Some of the innovations that will be used on this project include accelerated construction techniques in the form of precast components, high-performance materials, innovative contracting methods, intelligent transportation systems, and a structural health monitoring system.

The 24th Street Bridge over I-80/I-29 in Council Bluffs, Iowa, features full-depth post-tensioned deck panels supported on high-performance steel (HPS) girders. The two-span steel bridge will serve as the primary access to some of the most popular attractions in Western Iowa and will highlight the aesthetic theme for the I-80/I-29 corridor.

Several meetings were held in conjunction with this effort, ranging from constructability review meetings with the local industry to technology transfer meetings involving national experts. After meeting with local contractors to explore the feasibility of several accelerated construction concepts, a technology transfer meeting was organized and held in Omaha with participation from the Federal Highway Administration (FHWA), Associated General Contractors, fabricators, Iowa State University, and the University of Nebraska, along with the project team. The purpose of the meeting was generally to foster a transfer of technology among Iowa DOT, the Nebraska Department of Roads, and the FHWA in the area of precast concrete bridge components, with the 24th Street Bridge being of particular focus.

This paper focuses on some of the innovations associated with the design, fabrication, and construction of the 354 ft. by 105 ft. steel bridge. The information presented will help bridge owners, designers, and other industry professionals make the best use of high-performance materials and the latest innovations on future projects.

The 24th Street interchange project is the first part of a multistate (Iowa and Nebraska) effort to improve and upgrade the capacity of the Council Bluffs Interstate System (CBIS). The CBIS is composed of three highly congested corridors: I-80, I-29, and I-480. The 24th Street interchange serves major attractions and businesses such as casinos, a conference/event center, hotels, and major shopping outlets. Therefore, three lanes of traffic, one in each direction plus a turning lane, need to be maintained on 24th Street during construction.

Typically, a project of this magnitude is constructed over two consecutive construction seasons, but due to the critical location of this interchange traffic restriction duration on 24th Street needed to be limited to a single season (April–October). With this in mind, accelerated construction techniques along with innovative methods were primary features for this project, which made it a very attractive candidate for both the HfL and IBRD programs.
DESIGN CONCEPT

Design concept development for the 24th Street Bridge involved many considerations. Several bridge types and construction phasing options were considered to find the best solution to meet design and safety standards, facilitate traffic, and minimize right-of-way impacts. The existing four-span 216 ft. by 64 ft. prestressed concrete beam bridge spans five interstate traffic lanes. The proposed bridge needs to accommodate the future interstate expansion to a 12-lane dual-divided roadway section, with a I-80/I-29 centerline shift of approximately 42 ft. at the bridge. The project concept required 24th Street and I-80/I-29 to remain open during the phased construction of the new bridge.

A key constraint for the 24th Street Bridge was the shifted design location of the I-29/I-80 centerline, as it defined the location of the proposed bridge center pier. The solution for the 24th Street Bridge required that during the first phase of construction traffic be maintained between existing piers and the proposed center pier. Construction of additional piers to reduce span lengths was not feasible when considering existing, staged, and proposed roadway configurations.

The desired solution was the proposed two-span 354 ft. by 105 ft. welded plate girder bridge. Steel girders made this the most feasible option, as the required span lengths of 178.5 ft. and 175 ft. exceed Iowa’s prestressed concrete beam standards. Longer spans worked well for the interstate final lane configurations and allowed the flexibility to stage the I-29/I-80 traffic without reducing the number of traffic lanes during the phased construction of the bridge. The steel girder solution offers the contractor the flexibility of installing shear connectors in the field after the placement of deck panels, which provides more tolerance and an opportunity to make any needed adjustments.

Another advantage to the use of steel girders was from an aesthetic point of view. The use of steel girders complemented the use of other aesthetic features on this structure, such as the aesthetic terrace wall features designed to add interest to each bridge berm, as illustrated in Figure 1.

![Figure 1. Artist rendition of proposed 24th Street Bridge](image)

The proposed bridge cross section consists of six lanes (two lanes in each direction plus two turn lanes) along with a raised median, raised sidewalk, and raised multiuse trail. While the additional bridge length will accommodate the widening of I-80/I-29, the wider bridge roadway will improve traffic flow on 24th Street.
As discussed previously, the intent of this project is to stage-construct the new bridge in two phases while maintaining traffic on both 24th Street and I-80/I-29 at all times, with the exception of limited night closures. Figure 2 provides a good description of the staging sequence for this construction project. Both phases of construction will be completed in one construction season, with a spring start and fall completion. This aggressive schedule will require the use of innovative design, contracting, and construction techniques.

Figure 2. Bridge construction phasing

The two major components for the acceleration of the bridge construction involve (1) the use of full-depth, full-width precast deck panels, in lieu of a traditional cast-in-place concrete bridge deck application, and (2) accelerated contracting techniques (A+B bidding with incentives) along with a delayed construction start to allow lead time for steel fabrication.
The bridge deck uses full-depth precast deck panels with panel widths comprising roughly half of the new bridge width in each of two primary phases. A longitudinal closure pour will be utilized at the juncture between each half of the bridge deck. To improve ridability and provide an additional level of protection for the post-tensioned deck system, the panels will be topped with a high-density concrete overlay.

To ensure that the construction of this bridge will be completed in one construction season, bidders will be required to establish the number of calendar days to be used to complete construction. The product of the number of calendar days multiplied by a predefined daily user cost plus the contract sum will determine the winning bidder (A+B). The maximum allowable number of calendar days will be stated on the proposal. Bids showing time in excess of this maximum will be rejected. With this contracting method, it will be imperative for the contractor to complete construction within the specified days and avoid the cost of additional days.

STEEL FRAMING

The superstructure is made out of precast/prestressed concrete deck panels supported on steel girders. Steel girders were chosen for the main load carrying system due to two main factors: the span lengths and the vertical clearance. Steel also offered other advantages, such as better compatibility with the precast deck concept and the aesthetic theme. The span lengths were above the Iowa DOT limit for the use of their standard prestressed concrete bulb tee beam, and the constraints on vertical profiles required a shallower than optimum girder depth. The use of steel girders enabled greater flexibility to achieve the most feasible bridge design while maintaining the goal of accelerating construction.

The steel girders were designed to act compositely with the deck. This required that the deck be connected to the girders through the use of shear connectors. Composite action was achieved by the use of shear studs grouped together to maximize on the economy of deck panel fabrication and were evenly spaced at 2 ft. along the length of each girder. In addition, the plans allowed the contractor to install the shear studs in the field rather than having the studs installed in the shop, as is traditionally done with cast-in-place deck application. This shear stud installation method will allow the contractor greater tolerance for the erection of the deck panels in an expeditious manner. This is because the deck panels are not required to be set over already installed shear studs, and the contractor would be able to move the panels in all directions to maintain geometry control without being restricted by the location of shop-installed studs. Also, the installation of the shear studs in the field would not fall within the critical path for completion of this project.

The deck slab is supported by 12 lines of steel girders that are spaced at 9 ft. 0 in. on center with a maximum girder length between field splices of 121.75 ft. Because of the restriction to the girder depth, the design required the use of higher strength material than the traditional design. The designer determined the use of higher strength material for the bottom flange and the top flange between the two field splices of the pier section to be the most economical.

HPS 70W steel was used in these areas to take advantage of higher strength coupled with improved toughness and durability. All other steel, including the web, were specified to be A709, grade 50 steel. The web thickness of 1/2 in. required no intermediate stiffeners in the positive moment regions and a minimal amount in the negative moment zones. Cross frame diaphragms were generally spaced at 22 ft. The diaphragms consisted of two angle cross braces between two WT top and bottom struts. A plate diaphragm is specified between the two phases of construction, with one set of girder holes for phase one to be drilled and connected after the phase two superstructure is completed and most of the dead load has been applied.
DECK SYSTEM

After weighing all the factors, it was determined that each deck panel would be 10 ft. long by 52 ft.4 in. wide by 8 in. thick. Each panel will be pretensioned in the transverse direction with (20) 1/2 in. diameter, 270 ksi, low-relaxation strands. There will also be a total of 28 flat ducts embedded in each panel to house the longitudinal post-tensioning. Four 0.6 in. diameter, low-relaxation, 270 ksi strands will be installed in each of the embedded ducts. Pockets will be formed in the panels to accommodate headed shear studs to tie the deck to the girders to provide fully composite action with the deck in the positive moment regions. To provide economy of fabrication, phase one panels are geometrically similar to phase two panels. Each phase of the project will utilize 35 precast deck panels, for a total of 70 panels. The deck panels were designed in accordance with the latest edition of the AASHTO LRFD specifications. A plan view of a typical phase one panel is shown in Figure 3.

The deck panels will be installed after the steel framing (girders and cross frames) have been erected and the slab buildup below the deck panels has been formed. Slab build-up forming methods and the leveling of the panels to the correct elevation are left up to the contractor. However, the plans include optional leveling bolts embedded in the deck panels that could be used by the contractor to aid in setting the panels to the correct elevations (see Figure 4). After all the deck panels for a phase are erected, the transverse joints will be filled with high-strength, non-shrink grout.
Figure 3. Typical precast slab panel, showing embedded PT duct
This project utilized a female-to-female transverse joint between panels, eliminating the need for match casting and reducing the risk for damaging panel edges during erection and post-tensioning. The decision to use this type of joint was largely based on Iowa DOT experience with other projects that showed that this type of joint tended to perform better than other type of joints, especially where longitudinal post-tensioning has been utilized. The transverse joint configuration in the panels is a very important aspect to the design and successful service life of the structure. A poor detail of the transverse joint could result in leakage of the joint material and spalling adjacent to the joint. The transverse joint detail along with the blockout for splicing the post-tensioning ducts are shown in Figure 5.

After the grout in the transverse joints attains required strength, the longitudinal post-tensioning force will be applied and locked off. Several factors influenced the amount of post-tensioning force that panels were designed to accommodate. LRFD specifications do not allow any tension in areas where auxiliary reinforcement is not provided. Tension in the panels was caused by the composite dead load, live load, and impact in the negative moment zone near the pier. This criterion controlled the post-tensioning design at the transverse joints between the panels. In addition, the depth of the panel can only accommodate anchorages for four standard strand tendons.
In order to determine the effects of long term losses, mainly creep and shrinkage, a computer model was created to estimate the losses at the end of the service life for the structure. This computer model was checked with hand calculation, utilizing loss formulae in accordance with the latest LRFD specifications. Analysis showed that the age of the panels along with the strength of the panels at the time of post-tensioning have a significant effect on the amount of losses due to long-term creep and shrinkage. In this case, and in order to maintain zero tension at the transverse joints, no more than 23% maximum loss of the post-tensioning force can be accommodated when considering all the factors mentioned previously. For example, a 6,000 psi strength panel would be required to be 100 days old before the post-tensioning force can be transferred to the concrete, while a 12,000 psi panel would need to be 28 days old before post-tensioning. With an October letting date and an expected June erection of the panels, this would require an accelerated winter fabrication schedule and storage of the panels. This could have resulted in an economic disadvantage to the project. To avoid this situation and in order to provide as much flexibility as possible during the construction stage, the contractor was given the option to design a concrete mix that would yield the required design strength while accommodating the contractor’s accelerated schedule and minimizing the fabrication costs.

Concurrent with the concreting of the haunch and the shear studs, the sidewalk and barriers could be constructed. To connect the barrier and the sidewalk to the deck panels, threaded inserts were included in the panels and capped so that no reinforcing steel extends out of the panels, thus simplifying, finishing, storing, and shipping.

After the shear stud pockets and the haunch concreting have been completed, the driving surface of the deck will be topped with low-slump, high-density concrete overlay. The same process is then repeated for the second phase of construction.

To tie the two phases of construction together, a longitudinal closure pour near the centerline of the bridge will be cast in place. The longitudinal closure pour is located in the middle of the center girder bay and is designed as a moment connection carrying the full positive moment. The location of the closure pour was dictated by the number of temporary lanes and the location of the girder lines. Another advantage of locating the longitudinal joint in the area of positive moment between the girders is that the top of the joint is always under compression, reducing the possibility of stress cracks and joint leakage. See Figure 6 for the details of the longitudinal joint.

![Figure 6. Longitudinal joint closure pour detail](image)

The final step of the bridge construction will be to construct the median with a similar construction method as that used for the barriers and sidewalks.
CONCLUSION

In conclusion, to achieve the goals set for this project the design incorporated details from past projects, as well as the latest in research in the areas of deck panels. Coordination among the designer, the owner, local contractors, and fabricators was key to developing an economical design that could be constructed under an accelerated time frame. Some of the primary goals of this project are to minimize disruption to the traveling public during the reconstruction of the 24th Street interchange and enhance safety during and after construction.

Steel girder framing offered the best compatibility for use with a post-tensioned precast deck system for which construction acceleration and long-term durability were the key objectives. Furthermore, horizontal and vertical clearance requirements in terms of maximizing span length and minimizing superstructure depth, respectively, were best served with the use of steel girders. The natural look of weathering steel blended in with the overall aesthetic features.

As this project is scheduled for letting in October 2007 and construction in 2008, the performance of the innovative components will be closely monitored and evaluated. The success of these innovations, along with lessons learned, will be the basis for implementation on future projects.