CONCRETE INNOVATIONS ON I-235

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ABSTRACT

The early design planning of the 14-mile corridor included tremendous focus on the use of high performance materials, expanding the capabilities of standard precast elements and aesthetics. More than 70 bridges were rebuilt as a part of the I-235 Reconstruction project. The Iowa DOT worked closely with the contracting community and the precast concrete industry during the planning and design stages to cooperatively anticipate any difficulties posed by the new and unusual concrete work.

As aesthetics were a primary consideration of this project, distinctive concrete pier and abutment shapes, concrete sound walls, and concrete retaining walls were explored and tested against the rigorous criteria of aesthetic merit, economy, constructability, and long term maintenance objectives. Concrete figured to be a very important medium by which the design team could deliver the aesthetic results desired by the freeway's neighbors.

The end result of this collaborative effort gave the I-235 community an impressive display of aesthetically pleasing structures without compromising quality or long term performance.

Keywords: Aesthetics, High Performance Concrete, Self Consolidated Concrete, Precast Deck Panels, Post-tensioned Deck, Pretensioned Prestressed Concrete Beams, Context Sensitive Design.

INTRODUCTION

The Iowa Department of Transportation initiated a major challenge in early 1986 when it started the planning process for the reconstruction of the I-235 freeway in the heart of Des Moines, Iowa and the adjacent communities.

The I-235 project required the use of innovation in the form of materials, design and construction to overcome economical, functional, and environmental constraints. The I-235 reconstruction project in Des Moines is a six-year project that was started in 2002 and is expected to be completed in 2007. In addition to widening the existing facility to six continuous lanes, adding auxiliary lanes and upgrading all the interchanges, all structures located within the I-235 corridor are to be replaced or rehabilitated. The 426 million dollar project includes 26 concrete bridges.

AESTHETICS

Interstate 235 runs directly through the heart of Des Moines, and its potential architectural characteristics were not going to go unnoticed by the community. Special attention needed to be applied to the shaping, color and texture of many different structural elements of the freeway if the project would be deemed an environmentally sensitive neighbor to so many nearby residents and commercial interests. As a result, the project's potential for "making a statement" about Des Moines and greater Iowa was scrutinized during the planning and early design stages.

In keeping with the newly minted principles of Context Sensitive Design, meetings were organized early and often with community representatives, with the objective of forming a vision for the freeway corridor. Several different guidance committees were established for the purpose of reviewing major project decisions in real time, and consensus was built on many topics before moving forward to the next series of developmental issues.

I-235 AESTHETICS SUBCOMMITTEE

Beginning in 1998 and continuing for more than two years, the Iowa DOT engaged in a significant public involvement effort with community and local business representatives to determine the most appropriate aesthetic design theme for the interstate corridor. The community participants were organized into the I-235 Aesthetic Subcommittee, which advised the I-235 Steering Committee on all aesthetic issues. A team comprised of local, national- and international-caliber consultants was hired to coordinate the effort and to devise the enhancement concepts that were presented to the DOT's public partners[1].

All aspects of the freeway's essential elements were evaluated for aesthetic enhancement opportunities. Representatives of the Iowa DOT's many disciplines, including structural design, materials, and maintenance were given opportunities to review and adjust proposals as they emerged. Many ideas were proposed that could not be pursued due to economic,

constructability or maintenance concerns, but gradual progress was made toward a unified and achievable project enhancement plan.

As a result of the many discussions with the Aesthetic Subcommittee, a list of desires for the design character of the rebuilt freeway was enumerated, including:

- Showcase Iowa's Capitol City
- Unify and enhance the roadway
- Promote "Timelessness" in the design of bridge and roadway structures
- Create a linear urban park
- Accentuate community gateways
- Clean, elegant and simple designs
- Make aesthetics integral to the structures
- Buffer neighborhoods from roadway noise and visual pollution
- No hammerhead piers

DESIGN DEVELOPMENT STUDIES

Some innovative bridge types were briefly investigated during the early conceptual phase of design. Since the Iowa DOT had committed to a "limited build" scenario - wherein the new freeway would be constructed almost entirely within the existing corridor footprint with minimal new right of way required - significant changes to grade conditions were out of the question. This led the design team to consider a number of inherently slender bridging solutions such as channel bridges and even a number of cut-and-cover tunnels for some braided ramp conditions. In the end, however, the Iowa DOT found ways of reorganizing freeway components to accommodate its traditional concrete and steel beam stringer bridges for nearly all structures carrying or traversing the interstate.

In addition to the big-picture bridge configuration proposals, a number of challenging design suggestions were made for individual bridge components. It became clear very early on in discussions with community participants that bridge pier shape would be very important in expressing the architectural theme of the corridor. The local citizens' disapproval of traditional pier cap cantilevers was one clear guideline that drove the design process toward more unique shape solutions.

FINAL AESTHETIC CONCEPTS

Once the corridor's visual theme was complete, guidelines for designers were documented in a Master Aesthetic Plan. Many components of this plan were to be carried out in concrete, so this work had to be done carefully if it was to be one of the primary mechanisms used to convey aesthetic quality. All aspects of completing the architectural vision - from design to construction - were subject to greater control than on the average project.

Once the concept plan reached its final form, the task of transforming the concept into a constructible reality was undertaken. Because of time constraints during conceptual

development, it had not been possible for the design team to apply the conceptual ideas to all possible structural variations that would be encountered throughout the corridor. The Iowa DOT translated the architectural concept into workable details that could be successfully married to many standard details in order to streamline the process of incorporating the aesthetics. These core guide details were then provided to individual consultant and in-house designers to ensure consistency in the way that the architectural details were expressed in the built work.

Unique to Iowa, the chosen Delta piers reflect the arch theme that permeates the corridor's architectural features through the use of elegantly curved columns that in some configurations trace the limits of an arch between them (Fig. 1). The pier is further articulated by incorporation of columns 8 inches wider than the pier cap, which allows the superstructure to appear to bear directly on the outermost columns, suggesting an unbroken line of force in the resulting form. The piers also give a sense of permanence and strength through a visual mass that is much more substantial than the typical, sometimes "spindly-looking", round column solution. The large column cross section allowed for fewer columns in the average pier, which was seen as another visual benefit.

Fig. 1 Delta piers

The abutments provide an appropriate visual termination for the signature arched pedestrian railing used on all overhead bridges through the 14-mile corridor. These are conceived as "bearing blocks", resisting the thrust that appears to be imposed on them by the gracefully arching fence. All surfaces of these extended wings are rusticated similarly to the piers for continuity in appearance (Fig. 2).

Fig. 2 Abutment end post

Retaining walls and sound walls, although not seen as key elements in an architectural sense, had to be successful in establishing a clean, consistent backdrop for the more dramatic aesthetic enhancements occurring on bridges and in the landscaping. Precast retaining wall panels, for example, had to conform to one shape even if supplied by different manufacturers. The Iowa DOT specified a non-proprietary square shape for these panels, so that any potential supplier could competitively bid the work. The final appearance of cast-in-place, soil nail, and mechanically-stabilized earth retaining walls, and that of the sound wall system all had to be seamlessly compatible when complete. Surface treatments were kept simple - just a repeated vertical rustication was used - so that all of these structures had similar visual qualities (Fig. 3).

Fig. 3 Retaining walls

Sound walls were further distinguished from other secondary structures through the treatments employed on their back sides. This became another opportunity for further community and neighborhood involvement in terms of the selection of residential-side concrete textures (Fig. 4).

Fig.4 Sound wall residential side texture

CONTRACTOR CONSTRUCTABILITY MEETINGS

Another aggressive project preparation strategy used by the Iowa DOT was a series of early meetings open to all area contractors. This forum became the primary communication method for all matters of constructability.

While these meetings were used primarily to discuss the construction impacts likely to be experienced during such a large freeway construction project, they also provided the opportunity to review the new construction details associated with the aesthetic concepts. This proved especially beneficial to the development of the Delta Pier, which was a distinctly new challenge for the local contracting community. Many of the corridor's new design features were first introduced to contractors in these meetings, which meant that by the time project plans were published and distributed, most contractors had already become familiar with the project's unique construction requirements.

Once construction on the corridor's first projects was underway, the regular meetings continued as the best way for sharing information and creating construction strategies.

FORMWORK INDUSTRY COORDINATION

As part of the Iowa DOT's commitment to the new Delta Pier shape, guidance was sought from nationally recognized concrete formwork manufacturer EFCO, conveniently located in Des Moines. While most area contractors were tooled up for Iowa's standard round column pier type, the Delta Pier shape presented potential growing pains for some local contractors who did not own their own steel form panels. EFCO's formwork rental program eased that burden, and their formwork designers partnered with Iowa DOT staff to devise ways of accommodating the multiple variations of Delta Pier shapes required (Fig. 5). If the new pier shapes were to remain economical, a certain amount of standardization in the forming setups was necessary. It would also help the contractors a great deal if formwork was consistent from job to job.

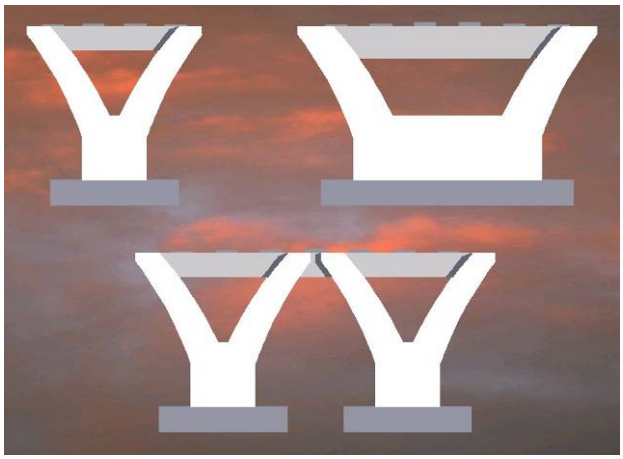

Fig. 5 Delta pier design variations

Forming accuracy and final concrete finish were seen as critical to the new pier shape's visual success. The use of steel forms for the subtly curved, rusticated columns was made a requirement, while the more flexible setup of MDO-faced plywood forms was deemed acceptable for the complicated upper section of the pier (Fig. 6). No forming restrictions were applied to any other cast-in-place bridge components.

Fig. 6 Delta pier column and cap formwork

SIGNATURE PEDESTRIAN BRIDGES

The I-235 corridor aesthetic concept had two dimensions. First, a consistent, reasonable and economical approach to enhancement of the entire corridor for parity and consistency, and second, an opportunity to create community identity. Three pedestrian-only crossings of the freeway provided the means for this second, more ambitious, goal.

The Iowa DOT and its design team studied a number of different bridge types for the pedestrian crossings, but quickly settled on arches for these structures, given the community's desire to associate itself more strongly with its arched bridge heritage. The tall, dramatic single-span arches provide a refined counterpoint to the workhorse multi-span stringer bridges, and their natural portal shape creates an inviting gateway impression for motorists passing underneath (Fig. 7). Abutments were shaped to complement the shape of the fence end posts on the overpass bridges, with additional shaping to resolve the bearing area and the real - not simply visual - thrust of the arches.

Fig. 7 Basket handle arch pedestrian bridge

CONCRETE COATINGS

Considering the amount of effort invested in the planning and design of the aesthetic features for bridges in particular, it seemed to the design team that something should be done to draw more attention to the unique features. Additionally, some community members voiced concerns over the potential for unpainted weathering steel girders to stain substructure

concrete, and concrete coatings were considered as one way to reduce or manage this consequence.

Following some unfortunate concrete surface finish failures related to an aging specification for cementitious coatings, the Iowa DOT revamped its approach to aesthetic concrete finishes. A new generation of pigmentable, high-silicone acrylic sealers appeared to be a much more reliable means of achieving durable coating performance. A new specification with tight controls on surface preparation was developed to ensure lasting results.

Concrete coatings work was packaged into separate, multiple-bridge contracts to economize the work and to remove this unusual component from the bridge contractor's responsibility. Concrete surfaces with a year or more of weathering are more receptive to aesthetic coatings, so waiting a few seasons after bridge completion to perform the coatings work is also advantageous.

The coatings provided the accent needed to enhance the prominence of the aesthetic features (Fig. 8). In addition, the thermoplastic nature of the sealer allows recoating for graffiti mediation or rust stain cover-up without the problems associated with multiple-coat paint systems. A blue accent stripe of acrylic emulsion paint was used on mainline bridge concrete rails to match the blue paint used on the pedestrian bridges, fencing, and steel traffic railings throughout the project. The blue is a match for that found on the Iowa state flag.

Fig. 8 Coated bridge concrete

ENHANCEMENT COSTS

A total project enhancement budget of 5% of construction cost for all structural and landscaping work was set before planning and design began, and the Iowa DOT held to this figure throughout construction. Bridge enhancements generally ranged between 7% and 12% of construction cost, with variations dependent on factors such as bridge length and width, pier configuration, construction days allowed, staging requirements, and constrained local working conditions. The average overpass bridge was enhanced at about 10% of construction cost, while mainline bridges received about a 5% enhancement budget. The Delta pier type required roughly double the labor cost of a traditional multi-column frame pier according to some contractors, meaning an approximate $20K per pier in added cost. Aesthetic treatments employed on walls were negligible, by comparison. Aesthetic pedestrian fencing was responsible for about half of the enhancement cost on most overhead bridges, and a painted steel-on-concrete traffic barrier singularly represented a 3% enhancement cost on some bridges.

STRUCTURAL INNOVATIONS

The I-235 Reconstruction project has given the Iowa DOT the opportunity to introduce innovative materials such as High Performance Concrete (HPC) and Self Consolidating Concrete (SCC) along with a new generation of Bulb-T prestressed concrete beams, all newcomers to Iowa. These innovative materials along with a post tensioned deck system made it possible to employ aesthetic features and gave the City of Des Moines three signature pedestrian bridges.

HIGH PERFORMANCE CONCRETE

Although HPC had been widely used in the United States in early 2000, deploying the HPC mix in Des Moines was not a simple task. A group of Iowa DOT engineers from various disciplines (Design, Materials, and Construction) collaborated on developing mix designs and construction specifications that are suitable for central Iowa. The HPC mixes had to utilize locally available aggregates and meet the design requirements in term of strength and permeability.

Along the way there were many challenges encountered, ranging from the lack of local experience in producing high performance mix such as HPC and the implementation of an aggressive and strict policy on curing concrete within minutes of casting while dealing with harsh winter temperatures. Cooperation among DOT staff, contractors and material suppliers helped overcome these challenges. The end result was improved structural concrete in terms of higher strength and lower permeability with significant reduction in shrinkage cracking in decks.

For the I-235 project, the contract documents specified target values for both compressive strength and permeability in a set of special specifications that was referred to as

Developmental Specifications (DS)[2]. The minimum 28-day compressive strength for cast in place concrete was set at 5000 psi while permeability values for the deck and substructure concretes were 1500 coulombs and 2500 coulombs, respectively. Contractors did not have any problems meeting these target values. Although the DS gave the contractors the option to design their own HPC mixes, they chose Iowa DOT mixes that were proven to produce the desired characteristics. Precast concrete was covered under a separate set of specifications[3].

Although the use of HPC in Iowa is not officially implemented statewide, many of the characteristics associated with it are being added to the traditional mixes as the result of the successes achieved on I-235. Furthermore, some changes to Iowa's construction specifications are being introduced to take advantage of the proven practices such as improved concrete curing.

SELF CONSOLIDATING CONCRETE

SCC is becoming increasingly popular for precasting structural elements nationwide. In addition to decreasing production cost at precasting plants, SCC has proved to be a valuable tool for enhancing the aesthetics of structural members. Precasters in Iowa successfully used SCC to produce panels for the MSE retaining walls (about 400,000 square feet) and the noise walls (over 250,000 square feet) through out the I-235 corridor (Fig. 9). These wall panels achieved a high level of quality and aesthetically pleasing finishes.

Fig. 9 MSE retaining wall and noise wall panels cast with SCC

As for cast-in-place (CIP) applications, the use of SCC remains restricted to unique and special details due to the limited experience of local contractors. The Iowa DOT gave contractors the option to use SCC for CIP concrete on various details with complex geometry on the three basket handle pedestrian bridges (Fig. 10). After overcoming the initial difficulty of maintaining tight form work, the contractor was successful in achieving the desired outcome with CIP SCC.

Fig. 10 SCC arch bearing pad formed (left) and result (right)

NEW BULB-T BEAMS

In preparation for the I-235 Reconstruction project, Iowa DOT collaborated with the prestressed concrete industry in Iowa to introduce a new family of prestressed concrete beams. The new set of bulb-T beams provided a competitive alternate for medium span bridges that are typically constructed with steel girders. These beams proved to be a perfect fit for many of the two-span overhead structures carrying city streets over I-235.

Some of the characteristics of the new beams include AASHTO LRFD code compliance, HPC with lower permeability (<2500 coulombs) and higher strength (up to 9000 psi), efficient design with longer spans (up to 155 ft) and wider beam spacing (9'-3), and aesthetically pleasing shape.

The new bulb-T beam family was initially limited to two unique beam sections, BTC and BTD beam series, to meet immediate I-235 project needs and then expanded to include shorter and longer spans, BTB and BTE beam series as shown in Figure 11. The expanded beam family featured the use of 0.6" strands.

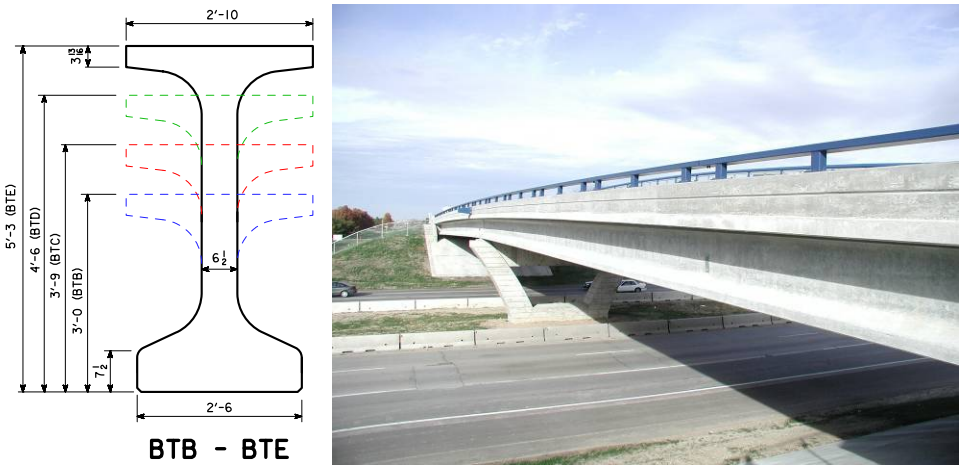

Fig. 11 Bulb tee beam cross section and BT beam as installed

POST TENSIONED DECK SYSTEM (BASKET HANDLE SIGNATURE BRIDGES)

A total of three basket handle arch pedestrian bridges, about 300 ft long and 10 ft wide each, span the I-235 freeway near schools and local attractions. An elegant and efficient deck solution for these structures was the use of post tensioned full-depth deck panels suspended from the arch ribs by pre-grouted high strength hangers. This was the first use of post tensioned segmental concrete deck in Iowa. By utilizing similar deck panel design, the match casting of the panels for all three bridges was performed by one fabricator allowing the re-use of specialty forms thus reducing the cost.

Fig. 12 Erection and post tensioning of pedestrian bridge deck panels

The panels of each of the three bridges were incrementally erected and post tensioned during a series of overnight lane closure with limited interruption to the I-235 traffic (Fig. 12). Two of the bridges required 22 panels each and the third bridge used 20 panels. These signature bridges incorporated innovative materials such as HPC and SCC.

The project's three arched pedestrian bridges received an FHWA Excellence in Highway Design award in 2006.

CONCLUSION

The I-235 project's success can be credited to many factors ranging from the use of innovations in design, materials, and construction to the high level of collaboration among the owner, designers, fabricators and contractors. High performance materials such as HPC and SCC will have lasting impacts on the longevity of the new structures as the result of lower permeability, improved consolidation and higher strength.

The use of concrete in the primary aesthetic features enhanced the look of the I-235 corridor and gave the affected communities a sense of pride in one of their busiest transportation facilities.

Successes and lessons learned from this project will benefit future corridor projects that are currently under design such as the Council Bluffs Interstate System, Interstate 74 in the Quad Cities, and US 20 across north central Iowa.

REFERENCES

1. I-235 Aesthetic Design Consultants:
   - RDG Crose Gardner Shukert, Inc., Des Moines, IA
   - Earth Tech, Inc., Des Moines, IA
   - J. Muller International, Chicago, IL
   - Joe Passonneau & Partners, Washington, DC
   - RDG Bussard Dikis, Des Moines, IA
   - Rosales-Gottemoeller & Associates, Boston, MA
2. Iowa Department of Transportation, Developmental Specifications: High Performance Concrete for Structures.
3. Iowa Department of Transportation, Developmental Specifications: High Performance Concrete for Prestressed Concrete Beams.