SEGMENTALLY PRECAST, POST-TENSIONED CONCRETE DECK FOR THE I-235 BASKET-HANDLE ARCH PEDESTRIAN BRIDGES

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ABSTRACT

As part of a major reconstruction effort on the I-235 Corridor through downtown Des Moines, Iowa, the Iowa Department of Transportation selected three elegant basket-handled arches to replace existing concrete cast-in-place box pedestrian bridges. The new arch bridges were to span the entire width of the highway corridor, which included six travel lanes and two exit ramps. The challenge for the engineers was to develop a long-span structure that could be constructed with minimal impacts to the highway traffic. This paper will discuss the segmentally constructed high-strength precast, post-tensioned concrete deck system selected to be suspended from the steel arches and will highlight the unique deck cross-section, the design and detailing challenges and the construction sequence.

Keywords: Segmental, Post-tension, Construction Sequence, Traffic Disruption

INTRODUCTION:

As part of a major reconstruction effort on the I-235 Corridor through downtown Des Moines, Iowa, The Iowa Department of Transportation integrated aesthetic enhancements into the detailing of all new bridge and sign structures.

Three existing cast-in-place concrete box pedestrian bridges were scheduled to be replaced as part of the reconstruction. The Des Moines community desired more than just three new aesthetically enhanced standard replacement structures. The community instead had visions of signature bridges that would become new "Gateways" for Des Moines. The Iowa Department of Transportation agreed and commissioned an aesthetic committee to develop the criteria for the signature designs.

The committee recommended three arch bridges that would span the entire width of the highway corridor. All three bridges would relate in appearance and would consist of slender steel "basket-handled" arches (two arch ribs leaned over to touch at the crown) that would span eight active lanes of traffic including six highway lanes and two ramps at each bridge site.

The challenge for the engineers was developing a long-span pedestrian structure that could maintain a sleek "light" appearance and could be constructed with minimal impacts to the highway traffic. Massive cast-in-place concrete abutments were utilized to allow the engineers to take advantage of traditional thrust arch design practices which minimize the bending moments in the deck by allowing the arch to be completely constructed prior to erecting any portion of the deck. A segmentally constructed high-strength precast, post-tensioned concrete deck system was selected to allow the contractor to erect the deck quickly without the use of falsework and without the need for lengthy disruptions to the highway traffic.

The first of the three signature basket-handle-arch pedestrian bridges was completed in December of 2003. Construction will begin on the remaining two bridges in the fall of 2004.

Looking northwest at completed bridge near the Botanical Center

CAST-IN-PLACE ABUTMENTS AND STEEL ARCH:

To maintain a sleek and slender arch, the abutments were designed to resist large horizontal thrust forces. With the abutments designed to resist these horizontal forces, the depth of the pedestrian deck could be minimized to create a lighter, airy feel for the bridge.

Sloping faces, linear reveals and sloping mask walls were utilized to reduce the scale of the exposed portions of the abutments and proportion them to the scale of the main steel arch and precast concrete deck.

The abutments were constructed in multiple concrete lifts due in part to the mass concrete pour requirements as well as the sequencing of the steel arch erection. Large erection frames were embedded in the concrete pours to facilitate accurate positioning of the steel arch.

The steel arch is comprised of two fully welded box shaped ribs uniformly tapering both in height and width from the base to the crown. The two steel ribs lean over and touch at their crowns forming a "basket-handle" appearance. The only bracing between the arch ribs occurs below the deck near the abutments.

Each steel arch rib was fabricated in three field segments. The arch was erected completely in the shop to ensure fit-up in the field as there was no room for error during erection. Only one nighttime closure of the I-235 highway was allowed and the contractor faced heavy penalties if there were delays in reopening the highway to traffic.

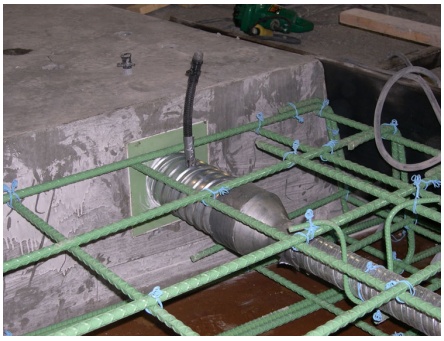
Threaded post-tension bars were used as hangers to suspend the precast concrete deck from the steel arch ribs. The post-tension bars were sheathed and grouted in HDPE pipes.

Cast-In-Place Abutments

Night time erection of steel arch ribs

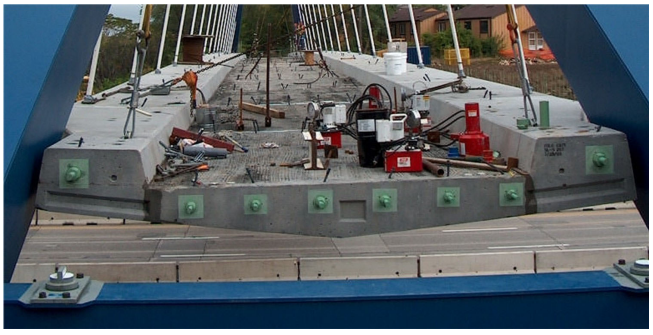
PRECAST SUPERSTRUCTURE - DESIGN & CONSTRUCTION FEATURES:

The bridge superstructure consists of six meter wide precast, post-tensioned slab panels suspended from post-tensioned bar hangers spaced at 4.2 meters. The slab panels narrow to 4.74 meters wide and pass through the arch ribs where they are supported on steel struts spanning between the arch ribs. A 6000 psi concrete mix was used and the panels were match cast to fit the vertical curvature of the bridge profile.



Slab panels were match cast to fit vertical curvature of deck

The slab cross section was created to meet the aesthetic detailing requirements for the I-235 corridor. The asymmetric slab panels tapered from 430 mm depth at the centerline to near 250 mm at the gutter line. At the gutter, the slab depth increased by 250 mm to form the curbs. The engineers used a 3-D grid analysis to determine the required distribution of post-tensioning across the slab section. The post-tensioning design required a unique combination of three different size post-tensioning bars to obtain the required eccentricities within the limited cross section. Placing 46 mm diameter bars high in the curb edge beams and placing the smaller 32 mm diameter and 36 mm diameter bars in the interior slab kept the overall post-tensioning group slightly below the slab centroid within the main span positive moment region. Two additional 46 mm diameter bars were added over the struts to shift the post-tensioning group eccentricity above the centroid to offset the large negative moment in that region. The post-tensioning arrangement resulted in zero design tension under all load cases at all locations.



Three post-tension bar sizes were utilized to balance the PT in the cross-section

The first of three bridges was constructed over eight lanes of active traffic with minimal disruption to that traffic. The precast post-tensioned slab panels were chosen to eliminate the need for any shoring, which would require lane closures. The slab panels were erected beginning at the center of the bridge moving outwards towards each abutment. The panels were supported during post-tensioning with temporary erection frames to the previously erected panel on one end and from the bar hangers on the other end. This process was repeated one panel at a time alternating sides to ensure that the bridge was never more than one panel out of balance about the centerline of the arch. The three panels beyond the hangers were supported temporarily with cranes until the post-tensioning was complete.

The Contractor was able to erect and fully tension one to two panels an evening allowing the slab panel erection to be completed within a short two-week period.

Precast panel lifted in place

Stressing of post-tensioning bars

Nighttime erection of precast deck

Segmental construction minimized traffic impacts

CONCLUSIONS:

This arch structure was born out of a design process that required the establishment of specific goals and criteria to obtain an efficient design that met stringent aesthetic requirements while allowing construction over eight lanes of active traffic. The family of three arch bridges was a significant investment in the Des Moines community that represents the best in engineering design and construction practices. Minimizing the disruption to the I-235 traffic was a major design consideration for the engineers and a deck system, which could be erected quickly and without falsework, was required.

Through the successful use of segmentally constructed precast, post-tensioned concrete, the goals for the design and construction of the structure were met. The structure met the "sleek" aesthetic requirements of the community, met the traffic challenges of the City of Des Moines and met the budget requirements of the Department of Transportation.

Aesthetic lighting completes the bridge near the Botanical Center