Minnesota Crosstown Project Features
Precast Concrete Segmental Bridges

by Keith Molnau, Minnesota Department of Transportation and Franklin Hines, FIGG

Precast segmental construction offered the most advantages and was the most attractive option

With the casting of this pier segment on October 18, 2007, Minnesota's first precast concrete segmental bridge gets underway. Photo: Mn/DOT.

The Minnesota I-35W/Hwy 62 Crosstown Project features precast concrete segmental bridges utilizing balanced cantilever construction within one of the most highly congested sections of interstate highway system in the region. Approximately 200,000 vehicles per day travel through the project, which is situated in the southern portion of Minneapolis and into Richfield, with the Mall of America and the Minneapolis-St. Paul International Airport nearby.

The old configuration was essentially an at-grade interchange. The traffic from Hwy 62 merged into the left-most (fast) lane of I-35W and caused traffic delays as the traffic wove together. This 1960s design had exceeded its design capacity, had a high accident rate, and was outdated with an aging infrastructure. Additionally, the area has long since undergone densely populated urban sprawl, with homes and businesses built to the edge of the right-of-way along the corridor.

The new layout includes elevated structures that separate the traffic and eliminate the merging and weaving requirements. The use of precast balanced cantilever techniques permits construction in these highly confined areas.

The $288 million contract, the largest in Minnesota's history, includes $99 million for bridges, of which $42 million is the total for the six precast segmental bridges. Construction began in 2007 and is on schedule for the planned 2010 completion date. This project was the first use of precast segmental construction in the state of Minnesota.

Bridge Type Selection

The bridge type selection process for these flyover ramps was based on a combination of several factors.

- The box girder geometry and balanced cantilever construction method offered an approach that better fits the confined work area.

profile

MINNESOTA I-35W/HWY 62 CROSSTOWN PROJECT / CROSSTOWN COMMONS, MINNESOTA

ENGINEERS: *(Each firm designed two segmental bridges)* PB Americas, Minneapolis, Minn. (Lead Designer), URS, Minneapolis, Minn., Parsons Transportation, Minneapolis, Minn.

ENGINEER: *(Project Layout, Staging Plans, and Roadway Plans)* SRF Consulting Group Inc., Plymouth, Minn.

CONSTRUCTION ENGINEERS: McNary Bergeron and Associates, Broomfield, Colo.

OWNER'S REPRESENTATIVE: FIGG Construction Engineering Inspection, Eagan, Minn.

PRIME CONTRACTOR: ALS– A Joint Venture of Ames, Lunda, and Shafer construction companies, Minneapolis, Minn.

SUBCONTRACTOR: High Five Erectors Inc., Shakopee, Minn.

CONCRETE SUPPLIER: Aggregate Industries, Eagan, Minn.

- The segments could be erected during brief night-time or weekend traffic closures.
- With six bridges comprising 461 precast segments, Minnesota Department of Transportation (Mn/DOT) believed the volume was sufficient to overcome the investment for a casting yard and provide an alternative that was more economical than other bridge types.
- Steel girder bridges were considered but deemed less desirable because piers necessitated integral caps that resulted in vertical clearance issues. Integral steel pier caps introduced fracture critical concerns Mn/DOT wanted to avoid. Integral post-tensioned concrete pier caps needed with steel bridges introduced vertical clearance problems due to falsework and the staged traffic lanes. Additionally there were long-term maintenance concerns.

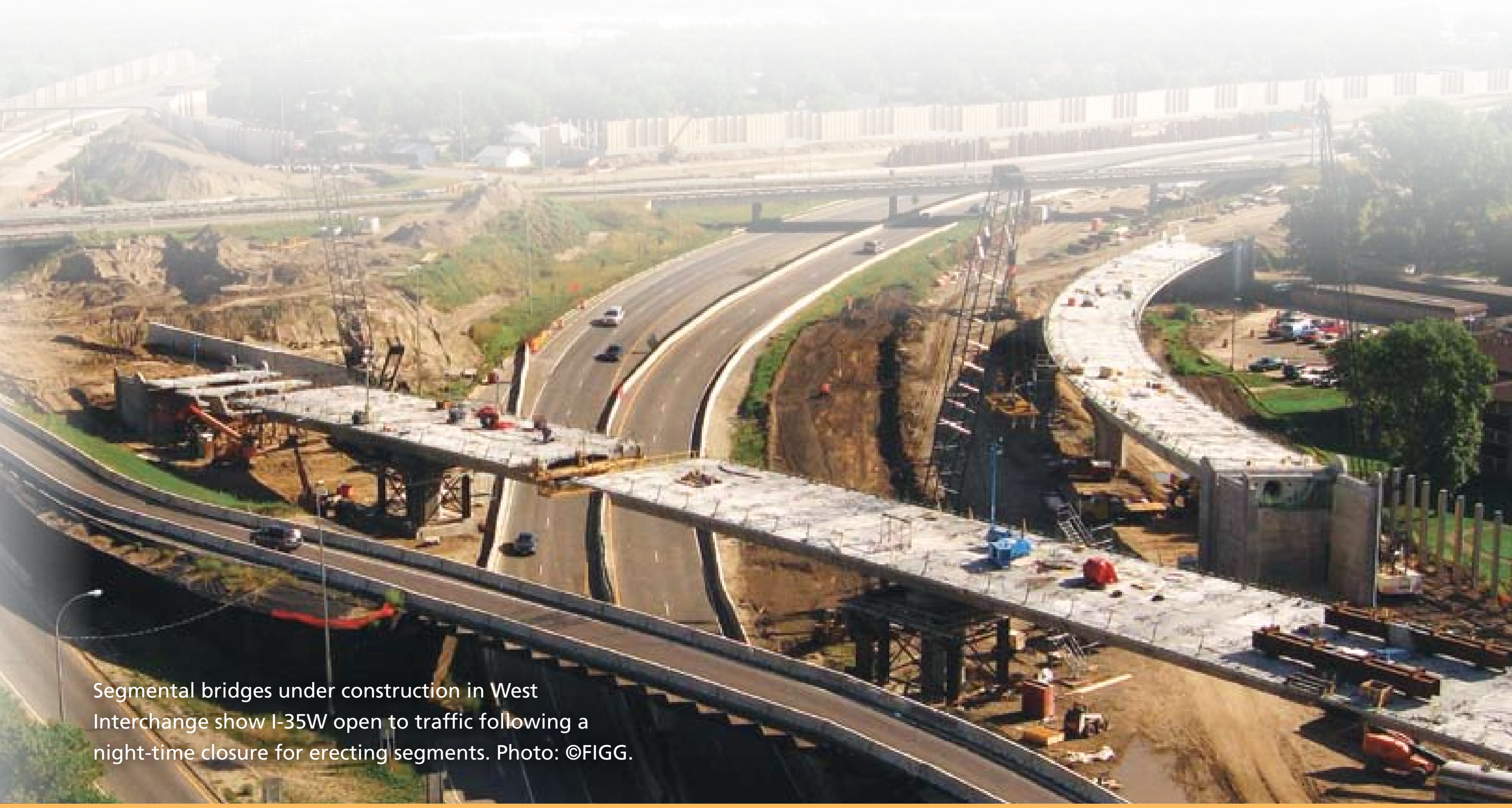
Considering long-term maintenance costs for future painting and deck replacements associated with steel girder-type bridges, precast segmental construction offered the most advantages and was the most attractive option.

Bridge Design Standards and Other Design Considerations

During design, a special effort was made by the lead segmental designers to standardize the precast segmental superstructure components.[1] Initial analysis included verification that one basic precast concrete section would be adequate for the project. In addition to the LRFD design loads, the section would suffice for the special permit truck loading cases required by Mn/DOT.

Therefore, a modified AASHTO/PCI/ASBI Section 8-2 (2400-2) was selected for all six segmental bridges, even though there were three unique roadway widths varying from 33 ft 4 in. to a maximum of 45 ft 4 in. The deck flanges would simply be narrowed or extended as needed to accomplish the bridge width variations. Also, the bottom slab thickness was increased to 24 in. at the pier then tapered to 9 in. thick for the typical precast segments.

More standardization was accomplished following the project letting. The contractor and his segmental specialty engineer wanted to adjust the tendon layouts to eliminate some double layer stacking in both the upper and



Segmental bridges under construction in West Interchange show I-35W open to traffic following a night-time closure for erecting segments. Photo: ©FIGG.

PRECAST, POST-TENSIONED BOX GIRDERS / MINNESOTA DEPARTMENT OF TRANSPORTATION, OWNER

FORMWORK FOR PRECAST SEGMENTS: Southern Forms Inc., Guild, Tenn.

POST-TENSIONING SUPPLIER: VSL, Grand Prairie, Tex. BRIDGE DESCRIPTION:

BRIDGE DESCRIPTION: Six precast concrete segmental bridges with 200-ft-long maximum spans

STRUCTURAL COMPONENTS: 461 precast AASHTO/PCI/ASBI Modified Section 8-2 segments

PRECAST SEGMENTAL BRIDGES COST: $42 Million (six bridges)

The East Interchange near Nicolet Avenue begins to take shape. The two bridges shown come together near a gore area, located off the bridges to allow for clearance of the full-width segments. Photo: © FIGG.

The use of precast balanced cantilever techniques permits construction in these highly confined areas.

lower corners of the box section where the slab thickens near the webs. The proposed changes were acceptable because the stresses in the structures were not significantly affected.

Such changes were reviewed in a streamlined shop drawing review process. In this process, the initial concept approval for a given change was made in advance by the respective designer. Then, final approval was made following a detailed review by the owner's construction engineer, requiring final concurrence from each designer. This streamlined shop drawing review process minimized review cycles and helped avoid delays.

Indoor Casting Facilities

The contractor established a casting yard on property they owned by converting a building into a short-line casting facility. Two sets of forms were used to construct all segments. One set of forms used adjustable form inserts so that it could fabricate pier segments, abutments segments, and typical segments. The second set of forms was non-adjustable and used for production of only typical segments.

Segments are cast, cured, transversely post-tensioned, and stored at the casting yard; approximately 25 miles hauling distance to the project site. Some 6 months after the notice to proceed, the contractor had cast the first segment on October 18, 2007. Casting was completed on January 22, 2009, for all of the project's 461 segments.

During the 2008 construction season, the contractor erected 248 segments, completing three of the smaller bridges in the project's West Interchange and portions of the three larger bridges in the project's East Interchange. The remaining 213 segments will be erected in spring 2009 when weather is favorable. Erection of segments throughout the winter is not practical due to restrictions on the required temperature for grouting operations and minimum temperature requirements for the epoxy in the match-cast joints.

Lessons Learned

Duct Couplers. Recently, post-tensioning suppliers have been urged to develop duct couplers that can be used at the joints of precast segmental bridges. The intent is to provide an additional layer of corrosion protection for the post-tensioning tendons at the match-cast joints. The Crosstown project initially had specified that duct couplers were required based on the Florida DOT's initiative with duct couplers. (See *ASPIRE*™ Winter 2008.)

After the Crosstown project letting, a prototype duct coupler was tested for acceptance. Couplers were cast into mock-up concrete test blocks. The duct with couplers was pressurized with compressed air to test for leakage and maximum sustainable pressure. The assemblage of the duct with the duct couplers was then grouted to also test the installation and grouting procedures and establish a safe upper bound grouting pressure.

When the specimen was cut apart at the joint and examined, the duct coupler was rejected by Mn/DOT based on an excessive void area within the coupler. The concern was that this void would trap water and chlorides that could lead to accelerated deterioration of the tendons and top slab. To resolve the situation, the couplers were eliminated from the contract. It was reasoned that the high-strength epoxy joint at the match-cast face offered adequate long-term durability and corrosion protection. Ultimately, proper attention was focused on match-casting operations so no grouting cross-over (grout leaking at the joints from one duct into another) was experienced during the entire 2008 season.

Segmental bridges under construction in the East Interchange showing traffic on temporary alignments. Photo: Mn/DOT.

Mn/DOT will not likely specify duct couplers on future segmental projects until the couplers from each supplier are fully developed, tested, and preapproved for use. Mn/DOT certainly wants to maximize corrosion protection of the tendons, but not at the expense of potentially reducing the service life of the bridge deck. The decks for these segmental bridges are critical to the longevity of the structures.

Falsework. Precast balanced cantilever segmental bridges are constructed with minimal use of falsework. However, four-legged falsework towers used adjacent to the piers are critical for structural stability during construction. The AASHTO *Guide Design Specifications for Bridge Temporary Works* includes a diagram showing a 1-ft-minimum set-back clear distance behind a barrier for falsework leg placement. This is shown for a tangent section of highway with full shoulder widths. The Crosstown project has curving, nonstandard temporary alignments weaving through the construction area with minimum shoulder widths.

Recent crash studies show that when a truck impacts a barrier, the upper portion of the vehicle extends beyond the barrier into what is termed as the "zone of intrusion." To maintain a safe work-zone, the falsework support legs cannot be allowed to be placed within this zone of intrusion.

The contractor understood the risk and responded to this issue by casting a temporary concrete wall, taller than the "zone of intrusion." Two legs of the tower were then fixed to the top of the wall.

Cold Weather Issues. The segment casting cycle allows a 3-day curing period after which the segment is moved into an outdoor storage area. Concrete test cylinders are kept with the segment during the initial curing period. When the segments are moved outdoors, the cylinders are put on an outdoor curing rack, which happened to be on the north side of the building. These control cylinders then become the basis for determining when the concrete reaches its required strength to erect the segment.

During cold weather, the required 28-day compressive strengths were not achieved on several segments. Prior to erecting these segments in the early spring, the contractor moved them and their corresponding cylinders to a heated enclosure to help increase strength gain. When the initial 28-day strengths were not met, additional cylinders were tested or, as a final step, the segments were cored and the cores tested. All segments eventually attained their required strength. The curing process must be carefully monitored and coordinated with the erection schedule to ensure the proper concrete strength is attained prior to erecting the segments.

Conclusion

Precast segmental bridges are proving to be economical and a good choice for the Minnesota Crosstown project flyover ramps. Being highly elevated structures, they are especially aesthetically pleasing and are expected to provide the added lasting value of low, long-term maintenance costs.

Reference

1. Tse, Joseph K., Paul J. Pilarski, Laura M. Amundson, and Keith Molnau, 2007, "Crosstown Segmental Design Standards," Proceedings of the PCI-FHWA National Bridge Conference, October 22-24, Phoenix, Ariz., 19 pp.

Keith Molnau is bridge design unit leader with the Bridge Office of the Minnesota Department of Transportation, Oakdale, Minn., and Franklin Hines is resident engineer with FIGG, Tallahassee, Fla.

For more information on this or other projects, visit www.aspirebridge.org.

AESTHETICS COMMENTARY

by Frederick Gottemoeller

Economy and elegance have a fruitful convergence in Minnesota's Crosstown Reconstruction. The Minnesota DOT has learned, as New Mexico, Florida, and other states did before them, that concrete segmental construction provides both an economical and attractive solution for flyover ramps in complex interchanges.

Let's start with the economics. In these interchanges the ramp widths can usually be sufficiently standardized to produce long lengths of bridges with similar widths. This means that there will be a large number of similar segments that in turn justifies the establishment of a casting yard. It also allows the standardization of the substructure, resulting in additional economy through the repeated use of a few standard pier forms. Once those economic basics have been met, the inherent advantages of the box girder come into play. The small footprint of the piers compared to a typical multi-column pier bent means there are more places to put the piers, a great advantage in a complex interchange. That, plus the fact that the critical vertical clearance point is often not on the bottom of the girder but on the bottom of the thin overhanging wing, usually eliminates the need for costly and unsightly straddle bents. Finally, balanced cantilever construction minimizes falsework and allows traffic to be maintained with minimal disruption, another savings.

All of these points of economy have their aesthetic payoff as well. First, the box girder, with its wide overhang and deep shadow line, looks thinner than a typical girder bridge of the same depth. The piers occupy a much smaller part of the visual field than typical multi-column pier bents. All piers are essentially the same, varying only in height. They don't have to be modified or rotated from place to place, as multi-column pier bents often do, in order to fit into tight locations. The result is an interchange that is easy to see through and to understand, a great advantage to drivers trying to navigate it. Finally, the girders themselves smoothly and continuously parallel the curves of the ramps. They fit right into the interchange. After all, an interchange is basically an assembly of curves.

Concrete blocks were cut apart for examination of the duct coupler where installation procedures were tested in this mock-up of a precast segmental joint. Photo: Mn/DOT.

The void area around the duct coupler raised concerns where chlorides could potentially collect in the top slab. The duct couplers were tested, but not used within any of the Crosstown segmental bridges. Photo: Mn/DOT.

Photo: Mn/DOT.

Precast segmental construction offered the most advantages and was the most attractive option.

Short-term closures occurred at night to allow for safe erection over traveled ways. Photos: © FIGG.

Photo: Mn/DOT.

A modified AASHTO/PCI/ASBI Section 8-2 was selected for all six segmental bridges

Photo: Mn/DOT.

Aesthetic Design Considerations

A total of 27 bridges were required for the project. These include a mix of bridge types, each serving a unique purpose. Of the total, 12 were precast, prestressed concrete girder bridges and six were precast concrete segmental bridges, five were steel beam bridges, one was a pedestrian steel truss bridge and three were temporary bridges. Compared with conventional construction, segmental structures have a relatively small footprint that allows for a radial placement of the substructures while allowing room to fit traffic lanes between the radial supports. The final plans were developed using an overall aesthetic design guide that reflects the desired architectural theme of the community and provides a uniform visual experience throughout the reconstructed corridor.

Pier shapes and other substructure components such as pilasters were also standardized. Split forms allowed the use of identical curved formwork on the tops of the fluted pier columns. To address variable slopes, the tops of pier caps were set to the nearest slope of 0%, 2%, 4%, or 6% with any additional variation taken up in the bridge seats. This allowed for repeatable use of side forms even with the variation in the superelevation transitions within the bridges.

The project also includes extensive use of precast wall components including precast mechanically-stabilized earth (MSE) wall panels and precast posts for noise walls. Details were also developed to standardize the connections between precast wall panels and the cast-in-place walls at the ends of the bridge abutments.

Aesthetics were considered in all aspects of the project through the use of a design guide that incorporated architectural themes. Photos: Mn/DOT.

Simple pier shapes, repetitive in nature, minimize the footprint of the bridge and reduce congestion in a complex construction zone. Photo: Mn/DOT.