WISCONSIN

Innovative research produces concrete results

by Aaron Bonk, Wisconsin Department of Transportation

Concrete bridges are an integral part of the nearly 14,000 state and local bridges along Wisconsin's transportation system. Approximately 70% of these state and locally owned structures are concrete and consist of concrete slabs, prestressed I-girder or box girder structures, culverts, and arches. Through research and the evolution of concrete technology, concrete has proven to be a durable and economical material for initial construction, as well as providing low life-cycle costs.

Accelerated bridge construction demonstrated with a geosynthetic reinforced soil-integrated bridge systems structure. All photos: Wisconsin Department of Transportation.

The Past

Wisconsin has a long history of concrete use for transportation structures. Many of the prestressed concrete girder structures remaining in service today were originally constructed in the 1950s. Wisconsin was one of the first states to use the American Association of State Highway and Transportation Officials (AASHTO) I-girder shapes in bridge construction. Precast, prestressed concrete AASHTO I-girders were used exclusively through the 1990s for new, prestressed concrete I-girder type structures. The shallower AASHTO shapes, such as the 28- and 36-in.-deep versions (Types I and II), are still used for new structures in Wisconsin today. However, current policy states that the deeper, traditional AASHTO prestressed concrete I-girder shapes are to be used only for rehabilitation projects.

Precast, prestressed concrete box beams, called box girders in Wisconsin were used concurrently with the AASHTO I-girders in the 1960s, 1970s, and 1980s on many state- and locally owned projects throughout the state. Due to performance and maintenance concerns, mainly related to reflective cracking of the bridge decks between adjacent box beams, use of this beam type on state-owned projects has been limited since that time. However, the relative ease of construction has proven to be a reason why prestressed concrete box beam structures are still being used for locally-owned structures today.

The Present

Beginning in the mid-1990s, the Wisconsin Department of Transportation (WisDOT) began investigating the possibility of introducing more-efficient, prestressed concrete, wide-flange I-girders to replace the deeper AASHTO I-girder shapes for use on new structures. WisDOT, along with the precast, prestressed concrete suppliers and national technical experts, conducted research to produce and adopt more-efficient girder sections that could be used for longer spans. One alternative studied was the use of higher strength concrete.

WisDOT adopted the use of 8 ksi concrete with the wide-flange I-girders, whereas 6 ksi concrete had been used with the traditional AASHTO I-girders. Concretes with strengths higher than 8 ksi were evaluated, but were not ultimately used due to the longer curing times associated with the higher strengths. Another design change increased the size of the bottom flange of the girders, which maximized girder efficiency through the number of strands able to be housed in the flange. The Wisconsin version of the prestressed concrete, wide-flange I-girders has been used extensively since the early 2000s.

WisDOT has also investigated improving the design details and fabrication techniques used with the wide-flange I-girders. In the early 2000s, as implementation of the wide-flange I-girders got underway, WisDOT inspection and maintenance engineers identified the frequent occurrence of end cracking of the girders immediately after production. Three types of cracks were noted: horizontal web cracking, inclined or diagonal cracking near the top of the girder web, and Y-shaped cracks near the bottom flange.

While the structural efficiency of the wide-flange girders was an improvement from the AASHTO shapes, the girder cracking introduced a significant maintenance concern. WisDOT's bridges are exposed to highly corrosive environments due to the widespread use of deicing chemicals on roadways in the winter months. Although it is WisDOT's policy to coat the exposed ends of girders, the development of these end cracks was a concern given the location with respect to the potential leaking expansion joints on the bridge deck.

Through research conducted by the Wisconsin Highway Research Program (WHRP), in conjunction with WisDOT and the University of Wisconsin, it was determined that the cracks were generated due to the high concentration of prestressing strands located in the girder ends and the large forces induced during fabrication. Researchers used finite element modeling in addition to measurements made at prestressing facilities to analyze the cracking issue and create recommendations for updates to the WisDOT girder designs. Cracking of the wide-flange girder shapes was especially prevalent in the

Accelerated bridge construction demonstrated with a precast concrete abutment.

Accelerated bridge construction demonstrated with a precast concrete pier cap.

heavily prestressed (54-, 72-, and 82-in.-deep) girders. The WHRP study of prestressed girder cracking provided design alternatives geared to reduce each of the three types of cracking. For horizontal web cracking, increasing the size of the vertical end zone reinforcement bars nearest the girder end helped to reduce the concrete tensile strains by nearly 50%. Regarding inclined or diagonal cracks, the best remediation approach was optimization of the number and spacing of draped strands. Finally, it was determined that the Y-shaped cracks near the bottom flange could only be prevented in heavily prestressed girders by methodically debonding the bottom strands. Debonded strands are currently not allowed in WisDOT prestressed concrete girders due to continuing concerns over long-term durability and corrosion resistance of the strands. This study may lead to an in-depth review of the current policy.

In addition to continuously working to improve the design of WisDOT's prestressed concrete, wide-flange I-girders, WisDOT is also involved with multiple studies to improve the performance of prestressed concrete box beam structures. Recently, a local WHRP study was initiated to review past applications of box beams; conduct a survey of professional experts to identify the extent and consistency of the reflective cracking problem with the Wisconsin box section; and to make recommendations for improved WisDOT design, detailing, specifications, and construction inspection policies. Along with the state-level WHRP study, WisDOT's chief development engineer is involved with a National Cooperative Highway Research Program (NCHRP) study related to connection details used with adjacent precast concrete box beam bridges.

The objective of this NCHRP research is to develop guidelines for the design of connection details to eliminate cracking and leakage in the longitudinal joints between adjacent boxes. Ultimately, WisDOT views these research opportunities as highly beneficial to the future use of box beam structures in Wisconsin, especially as they relate to accelerated bridge construction (ABC) projects.

The Future

As part of the Federal Highway Administration's (FHWA) Every Day Counts Initiative, WisDOT has successfully deployed numerous types of ABC projects and will expand their use in the future. One bridge in northern Wisconsin was constructed using geosynthetic reinforced soil–integrated bridge systems (GRS-IBS) technology. This project was constructed with the assistance of FHWA's Innovative Bridge Research Deployment program, which provided the opportunity for WisDOT to implement new ABC technology while incorporating cast-in-place superstructure technology. In addition, several bridges have been constructed using precast concrete substructure elements, multiple bridges have been placed using lateral slides, and one bridge was placed using self-propelled modular transporters (SPMTs).

WisDOT has for many years studied practical field applications for bridge structures. WisDOT views the research pertaining to adjacent box beam structures as something that could be extremely beneficial to GRS-IBS type structures. The GRS-IBS bridge that was completed in Wisconsin used a cast-in-place concrete slab span. The project proved to be highly efficient in regards to construction time; nevertheless, WisDOT views adjacent box beams as being an option that could decrease the roadway closures to an even greater extent.

WisDOT has also successfully employed the use of precast bridge elements and systems (PBES) as an ABC technology. Two projects, specifically using PBES substructures, were deployed using research conducted through a previously completed FHWA Innovative Bridge Research and Construction study. The first implementation of PBES used precast concrete abutments for a bridge carrying U.S. 63. This project was the first of its kind in the state and significantly reduced the abutment construction time from two weeks for conventional abutments to less than two days.

A subsequent project using PBES employed precast concrete pier caps at a nearby project site along WIS 25. This second project used lessons learned from the first PBES project to improve construction techniques and the overall efficiency of ABC technology. Specifically, the sizes and subsequent weights of the precast concrete elements were reduced in order to reduce the demand on construction equipment required for the project. It is anticipated that lessons learned from previously completed PBES projects will continue to reduce construction costs and timelines, along with lower life-cycle costs for these structures.

As structures continue to age and funding resources become increasingly limited, WisDOT will continue to emphasize the importance of research and applying it towards innovative methods using concrete. The practical application of this research, which is aimed at maximizing the durability and cost efficiency of our concrete structures, will become increasingly essential. WisDOT will continue to study and make improvements to concrete technology and its use in enduring structures.

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EDITOR'S NOTE

For more information about Wisconsin's bridges, visit www.dot.wisconsin.gov/projects/bridges.

To see a video of the bridge in northern Wisconsin that used geosynthetic reinforced soil–integrated bridge systems (GRS-IBS) technology, see http://www.youtube.com/watch?v=frxx9J7qiWU.