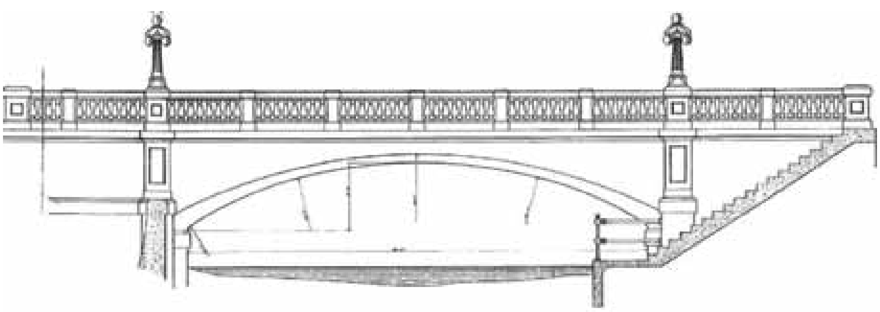
STATE

Concrete Bridges in Michigan—PAST, PRESENT, FUTURE

by Rebecca Curtis, Michigan Department of Transportation

Concrete structures are an important part of the bridge inventory of the Michigan Department of Transportation (MDOT). Several reinforced concrete arch structures built prior to the 1900s are still in service today. One example is I-69 BR over the Battle Creek River in Eaton County, an earth-filled spandrel arch constructed in 1921, which remains in fair condition 90 years later.

By the 1920s, simple-span reinforced concrete T-beams were the most common concrete structure type being constructed. In the 1950s, a significant portion of the reinforced concrete T-beams built were continuous spans, and in the mid 1950s, precast, prestressed concrete side-by-side box beams were common in Michigan. In 1959, precast, prestressed concrete I-beam bridges were introduced and, within a few years, prestressed concrete box beam and I-beam bridges dominated new concrete construction.



Battle Creek River Bridge is an earth-filled spandrel arch constructed in 1921 and remains in fair condition 90 years later. All photos and drawing: Michigan Department of Transportation except where shown.

A typical parabolic reinforced concrete T-beam bridge built commonly in the 1950s.

The Zilwaukee Bridge

When discussing concrete bridges in Michigan, one that must be mentioned is the Zilwaukee Bridge. MDOT made the decision to replace the existing I-75 bascule bridge over the Saginaw River in 1970, after it became apparent that a bascule bridge in an interstate freeway did not fit the purpose and need of the system. The decision to replace the drawbridge led to consideration of many alternatives. A tunnel under the Saginaw River would have cost about two and one-half times as much as a high-level bridge. Major alternatives for relocation of the freeway were also studied, but rejected as too costly and impractical. Closing the river to navigation at Zilwaukee also was considered but was opposed by the city of Saginaw and others with vested interests in maintaining port activity and its associated economic impacts upstream from I-75. Rerouting the traffic onto I-675 Business Loop through downtown Saginaw would have required extensive reconstruction well above the cost of a new bridge.

A high-level bridge was identified as the preferred option. Due to the Saginaw River being a strategic navigable waterway, the minimum height required over the waterway was 125 ft as dictated by the United States Coast Guard. The maximum highway longitudinal slope allowed in Michigan is 3%. These geometric factors contribute to the structure's grand size and length.

The twin precast, segmental concrete bridges are approximately 8085 ft long and the segments are 73 ft 6 in. wide between the tips of their

Following the 1950s, adjacent precast, prestressed concrete box beam bridges were very common in Michigan as shown in these elevation and underside photos.

The twin structures of the Zilwaukee Bridge over the Saginaw River are shown during construction about 1987.

cantilevers. The depth of the bridges varies from 8 ft 0 in. at midspan to 20 ft 0 in. at the piers. The precast segments were some of the largest used in segmental construction. A total of 1592 segments comprise the northbound and southbound structures. The northbound structure consists of 25 spans and the southbound structure consists of 26 spans, the longest of which is 392 ft over the Saginaw River.

Completed in 1988, the Zilwaukee Bridge has been in service for almost 24 years, and is currently in good to fair condition. The structure carries roughly 21.6 million vehicles each year, with the peak being between the July 4th and Labor Day holidays. A major rehabilitation project is scheduled for 2013, which will replace all pier, abutment, and expansion hinge bearings.

Concrete Today

In 2011, reinforced and prestressed concrete bridges made up nearly 52% of the more than 10,800 highway bridges in Michigan. Of these bridges, 3955 are prestressed concrete and 1652 are reinforced concrete. Generally, the concrete structures being constructed in Michigan today use precast, side-by-side box beams, spread box beams, or I-beams. Reinforced concrete is generally used for culverts, many of which are long enough to exceed the 20-ft limitation on the National Bridge Inventory inspection length. Current inspections find that concrete structures in Michigan are performing near the same or better than the average for bridges constructed during equivalent periods, with concrete structures outperforming the average for structures over 50 years old.

Concrete structures outperform the average for structures over 50 years old.

Advancements in concrete technology along with renewed emphasis on quality provide opportunities for MDOT to improve long-term durability and reduce the potential for uncontrolled random cracking in concrete structures. Given Michigan's harsh and often unforgiving wet, freeze-thaw climate, it is essential that concrete exposed to the elements be highly impervious to moisture and resistant to freeze-thaw deterioration. Acknowledging characteristics of high-performance concrete, MDOT is focusing its efforts on incorporating innovative performance features, such as, optimizing the gradation of aggregates, reducing the total cement content, utilizing higher volumes of supplemental cementitious materials such as ground-granulated blast-furnace slag, reducing the water-cementitious materials ratio to reasonable levels via chemical admixtures, and instituting upfront testing for and remediation of alkali-silica reactivity. In addition, MDOT recognizes that it is of upmost importance that the highest practical quality, freeze-thaw resistant

The Parkview Avenue Bridge uses five different types of precast components. Full-depth deck panels are shown after installation before grout placement in the joints and pockets.

The Parkview Avenue Bridge was designed as a total precast concrete structure to explore the concepts of accelerated bridge construction.

A scaled model of a deck bulb-tee bridge, 40 ft long and 14 in. deep, is shown in the structures laboratory of Lawrence Technological University and following testing to failure. The bridge uses carbon fiber prestressing strands, all nonmetallic reinforcement, and UHPC in the longitudinal joints. Photo: Lawrence Technological University.

aggregates are used in conjunction with a properly air-entrained, very low permeable matrix. Finally, in order to ensure a first line of defense against long-term deterioration of concrete bridge decks, MDOT requires that all exposed, freshly finished concrete surfaces be immediately covered with a saturated, highly absorptive burlap material, and kept continuously wet for at least 7 days using soaker hoses beneath plastic sheeting.

The Parkview Avenue Bridge

In 2008, MDOT began construction of the Parkview Avenue Bridge replacement using multiple prefabricated elements. The existing bridge was a two-lane county road over a four-lane freeway in Kalamazoo, Mich. The new bridge incorporated five prefabricated elements in lieu of the traditional cast-in-place construction. The project allowed MDOT to reduce the estimated construction time from 7 months to 2½ months. The successes and challenges of this project have laid the foundation for additional development of accelerated bridge construction technology in the state of Michigan.

The goal was to replace the existing bridge with a 249-ft-long, four-span bridge with a 23-degree skew in just 12 weeks. The prefabricated components consisted of four abutment segments, 12 round pier columns, 3 pier caps, prestressed I-beams, and 48 full-depth concrete deck panels. A 1½-in.-thick asphaltic overlay on a waterproofing membrane complete the bridge. The precast deck panels included a 250-sensor data collection system designed and monitored by Western Michigan University (WMU).

Due to alignment issues in the precast components, the bridge took nearly 6 months to complete, compared to the goal of 2½ months. The total project costs were within 2.5% of the as-bid amount. The monitoring system installed by WMU indicates that the bridge deck is performing as a unified segment and that the joints between panels remain properly tensioned in efforts to ensure that the composite design is being maintained. MDOT gained valuable experience on precast elements in construction and embraces the growing national movement toward accelerated bridge construction.

A Look Ahead

As MDOT looks toward the future of concrete bridges in Michigan, a clear vision is the necessity to develop a bridge preservation strategy that targets a 100-year service life. This is critical to maximize resources while minimizing the traffic impacts of maintenance and rehabilitation. A bridge designed for a 100-year service life must be able to meet the design, management, and inspection standards in practice today. Precast, prestressed concrete box-beams are advantageous because they have structural advantages over typical T-beam or I-beam sections. However, in the past, there have been issues with corrosion and inspectability with these sections. Through a Transportation Pooled Fund project (Solicitation Number: 1264), MDOT is pursuing a beam solution that incorporates the positive aspects of adjacent box beams while allowing for inspection access between the beams. This beam will facilitate accelerated bridge construction because the top flange serves as the deck surface, thus eliminating any cast-in-place forming. The beam is expected to be very long lasting because it will use noncorroding reinforcement including carbon fiber, stainless steel, and stainless steel-clad materials.

MDOT is currently conducting research through Lawrence Technological University in Southfield, Mich., to study the development and evaluation of a precast, side-by-side, deck bulb-tee beam bridge, which consists of the following:

- Precast deck bulb-tee beams prestressed and reinforced with non-corrosive strands and stirrups
- Integral transverse diaphragms precast monolithically with the deck bulb-tee beams and post-tensioned with unbonded noncorrosive tendons
- Ultra-high-performance concrete (UHPC) with the 28-day design compressive strength of 24,000 psi, used to fill the joints between the adjacent deck bulb-tee beams

The proposed research describes the deck bulb-tee beams as similar to shallow I-shape beams, except that the top flange is slightly wider than the bottom. This deck bulb-tee beam bridge allows proper inspection with the available space between the bottom flanges as compared to the box-beam bridge type.

Concrete bridges of all kinds are very important to the state of Michigan and have been for more than 100 years. These bridges have proven to be cost effective and durable. There have been significant advancements in technology in recent years including concrete, innovative designs, and noncorroding reinforcement. These, together with diligent quality control and preservation activities, lead engineers at MDOT to believe that the capability exists to build bridges very rapidly and achieve service lives of 100 years.

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For more information about the Transportation Pooled Fund Research project, contact Dave Juntunen, bridge development engineer at juntunend@michigan.gov, or call (517) 335-2993.