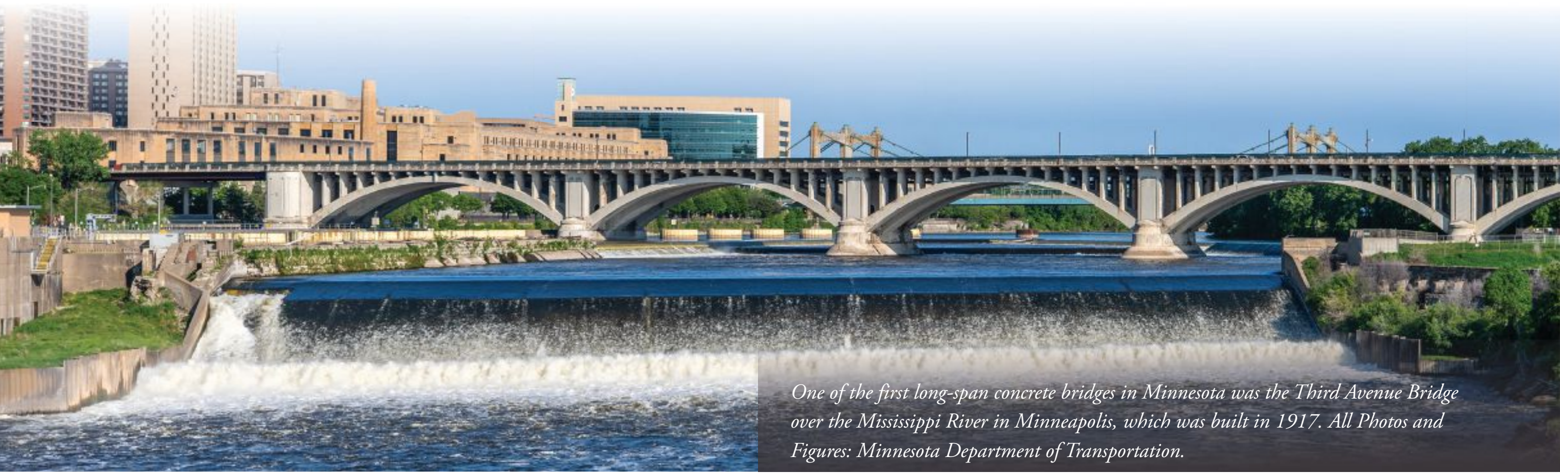
STATE

Minnesota

by Kevin Western and Arielle Ehrlich, Minnesota Department of Transportation



One of the first long-span concrete bridges in Minnesota was the Third Avenue Bridge over the Mississippi River in Minneapolis, which was built in 1917. All Photos and Figures: Minnesota Department of Transportation.

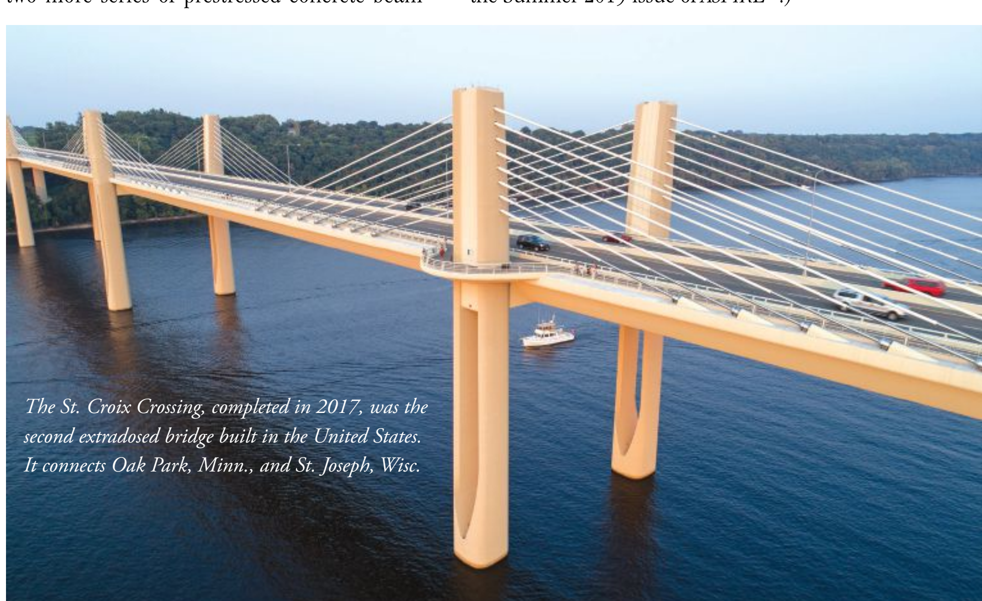
Minnesota is the land of 10,000 lakes and more than 10,000 concrete bridges. The Minnesota Department of Transportation (MnDOT) has been constructing and innovating using concrete bridges for more than 100 years. With high-quality aggregates readily available, the use of concrete has long been a logical choice for constructing durable, maintainable structures. The first long-span bridges in Minnesota were concrete arches, including the Third Avenue Bridge carrying Minnesota Trunk Highway (TH) 65 over the Mississippi River in Minneapolis, which was built in 1917.

By the 1950s, bridges in Minnesota were typically steel-beam bridges, concrete T-beam bridges, or cast-in-place concrete slab spans. Starting in the late 1950s, MnDOT, along with much of the bridge community, began using precast, prestressed concrete beams. By the 1970s, MnDOT had three regional fabricators, and the prestressed concrete beam became the preferred beam type for the agency because of its maintainability, cost effectiveness, and positive impact on construction schedules.

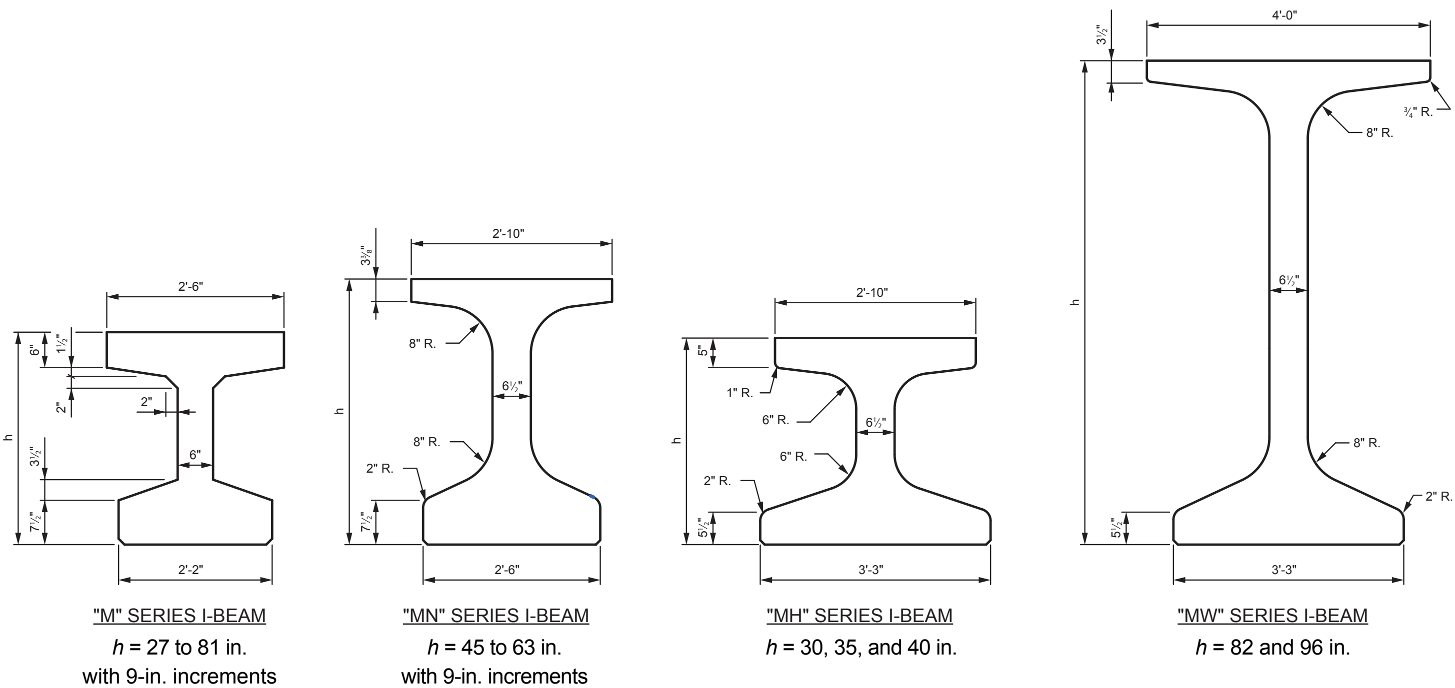
I-Beam Series

Over the years, MnDOT has constructed bridges with many concrete beam types, including I-beams, quad and double tees, bulb tees, rectangular beams, and, most recently, inverted tees. In addition to changes in geometry, concrete beams have become more efficient through improvements in materials; the maximum allowable concrete design strength has increased incrementally over the years from 5500 to 9500 psi. The I-beam continues to be the beam of choice. MnDOT has developed several series of I-beams over the last 25 years. The first, the M series, was developed in 1995. These had wider flanges than the AASHTO shapes that had been previously used. Over time, additional sizes were added until the depths ranged from 27 to 81 in. with 9-in. increments. Beginning with the first sizes published in 2005, MnDOT issued the MN series. With depths ranging from 45 to 63 in. with 9-in. increments, these beams had wider flanges and radiused, rather than chamfered, corners.[1] They could span farther at a given spacing or be spaced farther apart than the M beams for a given span length.

In the last 10 years, MnDOT has added two more series of prestressed concrete beam shapes. The MW beams have 82- and 96-in. depths for long spans that can exceed 200 ft. Most recently, MnDOT added the new MH series at 30-, 35-, and 40-in. depths. Both the MW and MH series use a 39-in.-wide bottom flange. The MW series uses a 48-in.-wide top flange, and the MH series uses the same 34-in.-wide top flange as the MN series. While the MW series is meant for very long spans, the MH series was developed to fill a gap primarily in the 75- to 105-ft span range. Previously, to meet those span lengths, a steel girder would likely have been necessary to prevent a drastic increase in structure depth. The MH beams, with their shallow depths, can avoid significant grade raises without the need for shoulder piers. (For details of the MH beams and their development, see the Concrete Bridge Technology article in the Summer 2019 issue of *ASPIRE*®.)



The St. Croix Crossing, completed in 2017, was the second extradosed bridge built in the United States. It connects Oak Park, Minn., and St. Joseph, Wisc.



The Minnesota I-beam series provides standard options for a wide range of design challenges.

Segmental Bridges

Although early long-span concrete bridges in Minnesota were arches, more recent long-span structures have been segmental box girders. The earliest uses of this style of bridge in Minnesota were two bridges over the Mississippi River: the Plymouth Avenue Bridge, built in 1980, and the Wabasha Street Bridge, built in 1996.

In 2003, the balanced-cantilever method was used to build the two Wakota Bridges, which carry Interstate 494 over the Mississippi River. Design issues identified during construction required adjustments and modification of details for the second bridge, but despite that, both bridges have been performing well.

Concrete box-girder bridge technology played a crucial role in the emergency rebuilding of the Interstate 35W Bridge over the Mississippi River (for more details, see the Project article in the Fall 2008 issue of *ASPIRE*). The new spans over the river are precast concrete segmental boxes, whereas the spans on the river shore are cast-in-place boxes constructed on falsework. The signature bridge opened to traffic in 2008 just over 13 months after the collapse of the previous steel-truss bridge. The project was completed using a design-build contract. While some of the prospective design-build teams proposed a steel girder bridge, the concrete segmental option was ultimately chosen for construction.

MnDOT has since constructed two more major Mississippi River crossings with segmental concrete bridges: the Dresbach Bridges, which were completed in 2016 and carry Interstate 90, and the Winona Bridge, which was also completed in 2016 and carries TH 43 adjacent to a recently rehabilitated historic truss bridge. (For more information on the Dresbach and Winona bridges, refer to Project articles in the Summer 2016 and Winter 2017 issues of *ASPIRE*, respectively.) Most recently, the St. Croix Crossing, the second extradosed bridge in the United States, opened to traffic in 2017. This bridge, with its graceful, curved piers and scenic St. Croix River setting, has become an attraction in its own right. (For details of the St. Croix Crossing Bridge, see the Project article in the Fall 2018 issue of *ASPIRE*.)

Precast Concrete Culverts

Precast concrete bridge culverts are the original form of accelerated bridge construction in Minnesota. Making up more than 40% of the bridge inventory in Minnesota, precast concrete box culverts are a cost-effective, low-maintenance, and easy-to-install solution for short-span bridges. Standard plans exist for boxes as small as 6 ft wide by 4 ft tall and as large as 16 ft wide by 12 ft tall, and they are used both for stream crossings and pedestrian trails. For areas of the state with little risk of debris accumulation, the boxes are often used in combinations of two or three lines to facilitate bigger crossings and accommodate a larger hydraulic opening. MnDOT is in the process of extending the standard plans to 20-ft spans.

A Bright Future

The future of precast concrete use in Minnesota is bright and exciting. In January 2021, MnDOT published a memo[2] directing designers to use 0.6-in.-diameter, 300-ksi strand tensioned to a maximum of 72% of the specified tensile strength ($0.72f_{pu}$) in all precast, prestressed concrete I-beams. With this change, beams can span farther than with 270-ksi strand. Also, fabricators are able to tension the 300-ksi strands at lower temperatures without needing to preheat the strands in the casting beds; this enables a longer and more cost-effective fabrication season—an important benefit given Minnesota's long winters.

MnDOT is also beginning a switch from harped strands to debonded strands for beams where the ends are encased in concrete diaphragms. MnDOT has historically required the use of fully bonded straight or harped strands only, not allowing debonded strands due to concerns with potential water and chloride intrusion at the beam ends. However, satisfactory in-service performance for beams with debonded strands located in states with similar climates has reduced the agency's concerns about corrosion related to debonded strands. Additionally, straight strands pose less of a safety hazard during fabrication than harped strands, and efficiency is not sacrificed with the use of debonded strands.

An exciting innovation on the near-term horizon for MnDOT and the concrete industry is the use of ultra-high-performance concrete (UHPC) for precast concrete beams. While UHPC can be used to produce extraordinarily long beams, there is tremendous value in using it for shorter-span beams, where bridges can be

The signature bridge that carries Interstate 35W over the Mississippi River is a concrete segmental box-girder bridge completed in 2008. The spans over the river used precast concrete segments, whereas the spans on the river shore were cast in place on falsework.

Kevin Western, the Minnesota Department of Transportation state bridge engineer, stands next to MW series I-beams, which include 96-in. depths for long spans that can exceed 200 ft.

constructed with shallow beams that can span farther than ever without grade raises.

No innovations happen in a vacuum: MnDOT's successful innovations with precast concrete, past and future, are all due to strong partnerships with their fabricators. The fabricators' willingness to consider new possibilities with open minds, make investments where needed, and facilitate change has been crucial.

Minnesota's legacy of innovation in concrete comes from a long line of leaders, including former Minnesota state bridge engineers, who led many of the innovations from the 1980s to today. They helped develop and evolve concrete usage in Minnesota by building a culture of innovation and bravery that is coupled with thoughtful caution and thorough review. This culture, along with the partnerships formed with fabricators, will continue to help Minnesota be a land of many more than 10,000 concrete bridges.

References

1. Minnesota Department of Transportation (MnDOT). 2021. *MnDOT LRFD Bridge Design Manual*. https://www.dot.state.mn.us/bridge/lrfd.html.
2. MnDOT. 2021. "Transmittal No. 2021-01—Memo to Designers #2021-01: Use of 300 ksi Prestressing Strand in Precast Pretensioned Concrete Beams." MnDOT LRFD Bridge Design Manual Update. https://www.dot.state.mn.us/bridge/lrfd.html.

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