Completed Trunk Highway 101 Bridge.
All Photos: Minnesota Department of Transportation.

TRUNK HIGHWAY 101 BRIDGE

by Paul Gronvall and Benjamin Jilk, Minnesota Department of Transportation

At the ground-breaking ceremony inaugurating the construction of the new Trunk Highway 101 Bridge reconnecting the cities of Chanhassen and Shakopee in Minnesota in June 2014, flood waters rose above the existing elevated roadway. As the rising waters slowly approached the ceremonial mound of soil that had been put in place to signify the breaking of ground on the project, they demonstrated why the project was needed. A flood-mitigation study was performed in 2011 to investigate ways to improve local and regional mobility during seasonal flooding events of the Minnesota River, which would force closures of the highway.

This crossing and the neighboring Trunk Highway 41 crossing in Chaska, Minn., had closed several times in the recent past, with closure times ranging from several days to several weeks and a projected cost to travelers of $1.675 million per day in 2030. The final design concept needed to minimize the risk of flooding without causing an increase in the 100-year floodplain elevation. A 4225-ft-long bridge across the Minnesota River floodplain was determined to be the preferred concept for mitigating flood risks by raising the bridge above the 100-year flood elevation and removing the existing causeway. The new bridge would provide four 12-ft-wide lanes for traffic, 8-ft-wide shoulders, and a 10-ft-wide multiuse trail separated from traffic to connect regional trails.

With a bridge being selected as the preferred concept to address flooding risks, an optimal bridge type that met all of the project requirements had to be determined. To arrive upon an optimal solution to span the floodplain, various combinations of substructure and superstructure types along with span configurations were considered as the final horizontal alignment and vertical profile were also being determined. Most of the water runs off the ends of the bridge into ponds where it is treated. Scuppers were provided at select locations to prevent ponding.

Pier Concept and Design

Selecting a pier concept to span the wide Minnesota River floodplain that minimized cost, schedule, and environmental impacts was of first importance. Open pile-bent piers are commonly used in Minnesota for bridges over streams and wetlands because they are cost-effective and relatively easy to build. Unlike typical concrete piers, open pile-bent piers do not require any temporary works be placed in the water to construct the

The existing causeway along with the temporary trestles served as a working platform during construction. Note the difference in the new and old roadway elevations.

profile

TRUNK HIGHWAY 101 BRIDGE / CHANHASSEN AND SHAKOPEE, MINNESOTA

BRIDGE DESIGN ENGINEER: Minnesota Department of Transportation, Oakdale, Minn.

PRIME CONTRACTOR: Ames Construction, Burnsville, Minn.

PRECASTER: County Materials Corporation, Janesville, Wis.—a PCI-certified producer

OTHER CONSULTANTS: Geotechnical engineer: Dan Brown and Associates, Sequatchie, Tenn.; Roadway engineer: Short Elliott Hendrickson Inc., St. Paul, Minn.

footing or any formwork to construct the columns. The piles within an open pile-bent pier function as both the foundation and as a permanent form to place the concrete infill while still being structurally utilized in the design. This type of pier lends itself to this application and was selected as the preferred concept for the Trunk Highway 101 Bridge.

Typically, the Minnesota Department of Transportation (MnDOT) limits the use of open pile-bents to sites where the height from top of pier to streambed is a maximum of 20 ft. For this project, the piers were significantly beyond this limit, with the tallest pier reaching a height of approximately 32 ft. Although these heights reached beyond the typical limit for open pile-bent piers, use of this type of pier was still the preferred concept. Therefore, further investigation was carried out to determine whether open pile-bent piers could meet structural demands and provide a safe route across the floodplain.

Based on the hydraulic report for the site, water flow rates during a flood event are minimal, if not static, and ice floes are not expected. Due to the low hydraulic demand on the site, an encasement wall around piles was deemed unnecessary and ice impact did not have to be included in the design.

Unique design criteria were developed to address the long-term durability and serviceability of the structure and its components while minimizing future maintenance needs. Serviceability—specifically, lateral deflection—was the governing factor in the design of the piers. There is a natural tendency of long bridges with relatively tall, flexible piers to "walk" or "migrate" in the direction of the longitudinal axis of the bridge under cyclic lateral loads such as braking and thermal forces. Criteria for limiting the lateral deflection of the piers were set to address this phenomena by reducing these longitudinal movements through the stiffening of the open pile-bent piers. Also, this stiffening of the piers aids in protecting the expansion joint glands from tearout and deterioration, and limits undesired expansion bearing movements. All of these measures should reduce future maintenance needs and costs.

The bridge was constructed in multiple segments. The spiral welds are visible on the steel pipe piles that were filled with concrete after driving.

Initially, multiple rows of smaller-diameter battered piles were considered to increase the stiffness of the piers. With 40 piers on the project, this approach would have resulted in a significant increase in the amount of piling required and presented challenges in maintaining reasonable construction tolerances at the heads of the piles, considering their heights above the ground.

Instead, a single line of larger-diameter piles was selected for the design. Although the individual piles were more expensive on a per-foot basis, the overall project cost was reduced because fewer piles were used and the simplicity of driving piles plumb also saved money. During final design, two concrete-filled composite steel pipe pile sections were chosen. To ensure and maintain a clean inside wall on the steel pipe pile, the pile bases were driven closed-ended and filled with concrete later. For the shorter piers at both ends of the bridge, a 16-in.-diameter steel pipe pile was used, and, for the taller piers, a 30-in.-diameter steel pipe pile was used. The 30-in.-diameter composite steel pipe pile section was the first of its size and the largest composite pipe pile section used on any open pile-bent pier in Minnesota.

The final design of the pile-bent piers included an analysis that considered both combined axial and lateral load effects along with nonlinear soil-structure interaction. This analysis was used to determine the fixity point of the pile below the surface of the soil and the associated effective length for buckling capacity computations of the piles. Because the design was governed by serviceability criteria (specifically, lateral deflection), it was paramount that the design and properties of the piles maximize the available composite action between the steel pipe pile

CARVER COUNTY, MINNESOTA, OWNER

BRIDGE DESCRIPTION: A 4225-ft-long, 41-span, precast, prestressed concrete I-girder superstructure with a deck area of 333,456 ft^2 on open pile-bent piers

STRUCTURAL COMPONENTS: Three-hundred sixty-nine 45-in.-deep precast, prestressed concrete I-girders; open pile-bent piers composed of 408 concrete-filled steel pipe piles (30-in. and 16-in. diameters) with cast-in-place concrete pier caps; abutments supported by fifty-one 12-in.-diameter concrete-filled steel pipe piles; and a 9-in.-thick monolithic concrete deck

BRIDGE CONSTRUCTION COST: $24.4 million bid cost (approximately $73/ft²)

Various techniques were used to construct the 13 deck segments in order to evaluate their effects on deck performance. Gang vibrators, as shown here, were used for one segment.

section and the 5-ksi concrete infill. Composite action is primarily achieved through two mechanisms: frictional bond transfer between the steel pipe pile section and the concrete infill and, for larger 30-in.-diameter spiral-welded pipe piles, the projection of the weld.

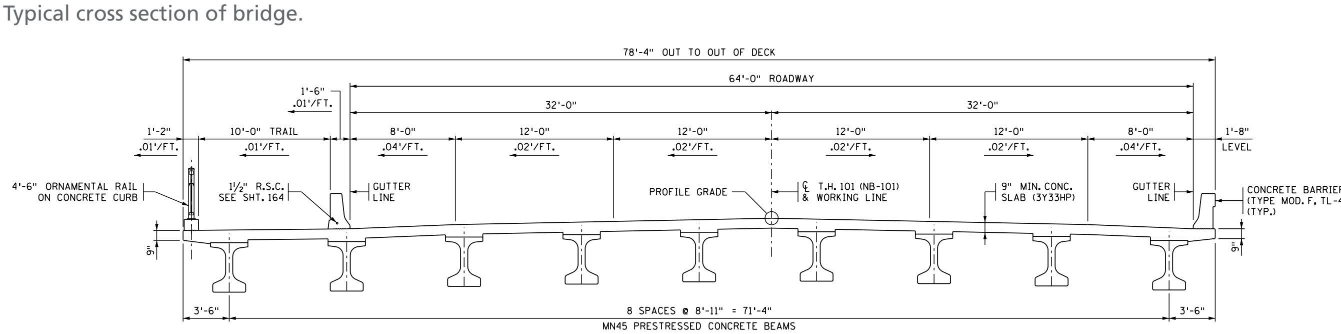
Because the upper portion of the piles is exposed to air and water, the piles were galvanized from the top of the pile to a minimum of 15 ft below the ground surface, to provide a level of protection against corrosion. Conventionally reinforced cast-in-place concrete pier caps were chosen for their simplicity and cost-effectiveness.

Precast, Prestressed Concrete I-Girder Superstructure

During the preliminary design phase, the preferred type of superstructure selected was precast, prestressed concrete I-girders. This girder type is a go-to solution in Minnesota for a low-cost and low-maintenance superstructure. Multiple suppliers in the area, quick turn-around time, and ease of construction make them the preferred option in most cases. For these reasons, precast concrete girders were the right solution for the Trunk Highway 101 Bridge.

To span between the piers, 45-in.-deep MnDOT girders were selected. The typical bridge cross section consists of nine girders spaced at 8 ft 11 in., with the last three spans varying slightly because of a curve at the end of the bridge. The spans range from about 87 ft to about 105 ft in length. There are a total of 41 spans in 13 units separated by strip-seal joints. A unit consisted of

Typical cross section of bridge.



three or four spans. The girders were designed as simply supported, but additional reinforcement was provided over the piers in the bridge deck where there was no joint.

Deck Used to Compare Performance of Parameters

The bridge deck is 0.8 mile long, and it therefore provided a great opportunity to incorporate different experimental items to compare concrete placement methods and performance of the concrete deck. With the bridge deck separated into 13 units, each joint formed a physical separation in methods for deck placement. The standard method for placing decks in Minnesota was used as the basis of the comparison, and all the other deck sections had more stringent specifications aimed at improving deck performance, durability, and quality.

The variations included the wet cure time, the number and type of vibrators required for placement, reinforcing bar chair spacing, the inclusion of fibers in the concrete, and the maximum aggregate size in the concrete. Every permutation tried outside of the standard method proved to help reduce cracking. Epoxy-coated reinforcement was used in all concrete elements of the structure that were not completely under soil to increase durability and improve performance.

The bridge is composed of 41 spans and 40 piers. The deck area is 333,456 ft^2 and is supported by 369 precast concrete I-girders utilizing 738 bearing assemblies. The total cumulative length of concrete girders on the bridge is approximately 7.2 miles. Overall, 459 piles (408 in the open pile-bent piers and 51 supporting the abutments) were used to construct the bridge—that is the equivalent of more than 10.4 miles of piles. More than 81.5 million pounds of concrete and 2.4 million pounds of epoxy-coated reinforcement were used on the bridge. The 4225-ft length makes it the longest bridge in Minnesota using only open pile-bent piers for support.

The new bridge, completed in November 2015, provides a cost-effective solution to improve local and regional mobility during seasonal flooding events of the Minnesota River, which had formerly disrupted traffic in the region.

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