PROJECT

MINNESOTA'S PRECAST COMPOSITE SLAB SPAN SYSTEM

This is Bridge 66004, TH 60 over the Cannon River in southern Minnesota after completion. Photos: Minnesota DOT.

by Moises C. Dimaculangan and Tony Lesch, Minnesota Department of Transportation

With aging bridge infrastructure and higher levels of traffic on roadways, the demand for bridge replacement and rehabilitation is very high. For this reason, there is a need to look for innovative ways to rapidly construct longer lasting bridges while reducing traffic disruption. One solution is prefabricated bridges. The Minnesota Department of Transportation (MnDOT) has embarked on the development of such a system. The system can provide an effective and economical design concept that can be implemented for new bridges and the rehabilitation of existing bridges.

In 2004, MnDOT state bridge engineer, Dan Dorgan, participated in an International Scan Tour sponsored by the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the National Cooperative Highway Research Program. The Prefabricated Bridge Elements and Systems scan team visited Japan, the Netherlands, Belgium, and France. The objective was to look for innovative ways for rapid construction of bridges while minimizing the impacts on the traveling public. The focus areas of the scan were prefabricated bridge elements and systems that minimize traffic disruption, improve work zone safety, minimize environmental impact, improve constructability, increase quality, and reduce life-cycle costs. The Scan Team identified 10 technologies for implementation in the United States.

Poutre Dalle System

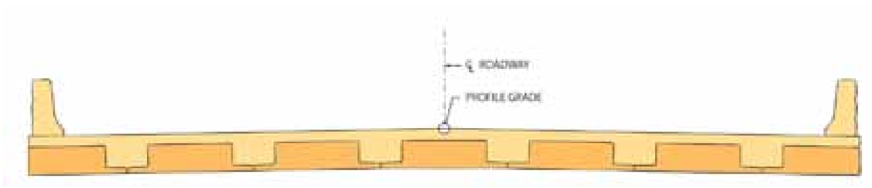
One practice in particular that showed promise in innovation of rapid construction was the Poutre Dalle System from France. This system consists of shallow, precast, prestressed concrete inverted-tee beams that are placed directly adjacent to each other. The beams are connected across a longitudinal joint that is established through the use of 180-degree reinforcement hooks that protrude from the sides of the webs. Cast-in-place (CIP) concrete is placed between the beam webs and over the top of the beams to form a solid composite cross section.

In Minnesota, CIP concrete slab span construction has a long history and a useful place in the bridge inventory where shallow depth structures are desired. But construction of the traditional slab span bridge can require large amounts of time and labor due to curing periods and formwork construction and removal. Impressed with the Poutre Dalle System, MnDOT began developing a similar system for use on Minnesota highways as a potential alternative to CIP slab span structures.

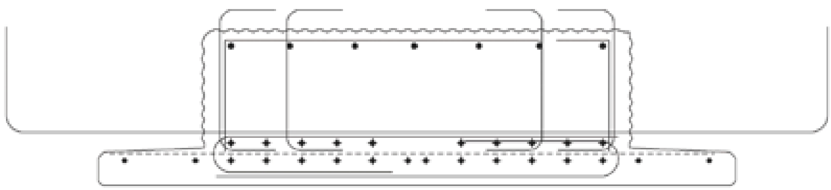
Minnesota's System

Bridge engineers in the MnDOT Bridge Office started the design process by first roughing out some initial design concepts that were discussed with several local precast beam fabricators. The team then created a partnership with researchers from the University of Minnesota. In a series of design workshop forums, the designers and researchers worked together to develop design details and an outline for a parallel Minnesota bridge research project. The research project was multifaceted research intended to instrument a pilot bridge to verify the design assumptions and to conduct additional research on beams in the university's laboratory.

Bridge No., Trunk Highway No., Bridge Name, and Location	04002, T.H. 72 over the Tamarac River, Waskish	13004, T.H. 8 over Center Lake Channel, Center City	33008, T.H. 65 over the Groundhouse River, Kanabec Co.	33005, T.H. 65 over the Ann River, Kanabec Co.
Year Built	2005	2005	2007	2007
Total Length	143'-11"	72'-5"	90'-8"	112'-5"
Width	50'-4"	76'-2"	66'-0"	47'-4"
Span Lengths	44'-11", 54'-1", 44'-11"	22'-0", 27'-0", 22'-0"	29'-7", 30'-4", 29'-7"	36'-5", 36'-10", 36'-5"
f'_c Precast and CIP, psi	6500, 4000	6500, 4000	6500, 4000	6000, 4000
Fabricator (PCI-certified producer)	County Materials, Roberts, Wis.	County Materials, Roberts, Wis.	County Materials, Roberts, Wis.	County Materials, Roberts, Wis.
Contractor	Robert R. Schroeder Construction Co., Glenwood, Minn.	Lunda Construction Co., Black River Falls, Wis.	Redstone Construction Co., Mora, Minn.	Redstone Construction Co., Mora, Minn.



A transverse section through a bridge using the MnDOT Precast Composite Slab Span system.



The cross section of a typical MnDOT Precast Composite Slab Span beam.

View of a longitudinal joint between precast sections before installing field-placed reinforcement.

View of a longitudinal joint after the placement of the "drop-in" reinforcing cage.

The new system is a combination of precast, prestressed concrete beams and the traditional concrete slab span system. The design team has referred to the new system as the Precast Composite Slab Span (PCSS) system. Similar to the Poutre Dalle system, it consists of a series of adjacent precast, prestressed concrete inverted-tee bridge beams that also serve as stay-in-place formwork for the CIP portion of the deck, eliminating formwork construction in the field. It also simplifies construction with innovations such as "drop in" reinforcement cages over the longitudinal joint connections between the precast sections. In addition to an overall reduction in construction time, the system provides other advantages including improved quality control, greater safety, and reduced environmental impact at the site. MnDOT's PCSS system is used for short span bridges (20 ft to 45 ft), a configuration that has been served by CIP slab span bridges.

During development, some design assumptions were made early on with the understanding that research would be necessary to validate the assumptions. The prestressing steel was designed using the AASHTO LRFD Bridge Design Specifications, Third Edition, 2004. Because the system is intended to act as a monolithic superstructure such as a slab span, the live load distribution was based on the Equivalent Strip Width for Slab-Type Bridges (AASHTO LRFD Bridge Design Specifications, Article 4.6.2.3). Similarly, the layout of the mild reinforcement in the CIP portion of the superstructure was designed similar to the top reinforcement of a CIP slab span bridge.

Pilot Projects

MnDOT implemented this new technology with two pilot projects in 2005. Bridge No. 04002 is located on MN Highway 72 over the Tamarac River near the rural, northern Minnesota town of Waskish. Bridge No. 13004 is located on U.S. Highway 8 over Center Lake Channel in Center City, just north of Minneapolis-St. Paul. The university research team

Bridge No., Trunk Highway No., Bridge Name, and Location	6679, T.H. 76 over the South Fork of the Root RIver, Houston Co.	49007, T.H. 238 over the Swan River, Morrison Co.	49036, T.H. 238 over Pike Creek, Morrison Co.	66004, T.H. 60 over the Cannon River, Rice Co.
Year Built	2007	2009	2009	2009
Total Length	n/a	104'-2"	72'-2"	124'-5"
Width	30'-0"	39'-4"	43'-4"	47'-4"
Span Lengths	19'-0"	34'-1", 34'-10", 34'-1"	23'-5", 24'-2", 23'-5"	40'-5", 40'-10", 40'-5"
f'_c Precast and CIP, PSI	4000, 4000	6500, 4000	6000, 4000	6000, 4000
Fabricator (PCI-certified producer)	County Materials, Roberts, Wis.	Cretex Concrete Products Maple Grove, Minn.	Cretex Concrete Products Maple Grove, Minn.	Minnesota Construction Harmony, Minn.
Contractor	MnDOT Bridge Maintenance	Lunda Construction Co., Black River Falls, Wis.	Lunda Construction Co., Black River Falls, Wis.	Minnesota Construction Harmony, Minn.

A precast concrete section being lowered into place adjacent to another during the rehabilitation of Bridge 6679.

instrumented and monitored the Center City bridge as part of the system development. The results of the field and laboratory study confirmed the system's durability and verified the slab span design assumptions. The projects revealed that the PCSS system is a practical and economical accelerated construction alternative to CIP slab span construction.

After a year in service, researchers detected cracking in the deck above the longitudinal joint between precast sections. Transverse cracks were also discovered over the pier locations, which may require ongoing maintenance. The strains at these locations have been monitored and have increased over time. According to researchers, these cracks appear to be the result of thermal gradient effects. As part of the project, they will continue to monitor the sensors and at the same time review and comment on the latest design methodology implemented by MnDOT.

Further Implementation

Because results from the initial field implementation projects were relatively favorable, six more bridges were planned and constructed in Minnesota with the intent to improve the system. Modifications were proposed by the researchers and lessons learned from the initial projects were incorporated. Three "2nd generation bridges" were designed and built in 2007. In order to phase in the design changes, only a few of the proposed modifications were incorporated into the 2nd generation bridges. Specifically, the changes involved modifications to the mild reinforcement in the girders. In 2009, three additional "3rd generation bridges" were designed and constructed that included a large number of the modifications with the hopes of reducing cracking. The most significant change was to make the bottom flanges of the beams thinner in order to reduce the amount of area causing the reflective cracking. Research test results also indicated that the thinner flanges helped improve the transverse load distribution of the system. Other notable modifications included:

- Increasing the chamfer sizes on the edges of the beam
- Increasing the transverse deck reinforcement bars using closer spacing
- Assuring the direct placement of the drop-in reinforcement cage such that it was staggered with the bars protruding from the beams
- Providing fixed anchorages between the superstructure and the substructure at the supports for the center 21 ft on both sides of the bridge center line and placing flexible foam around the anchorage dowels to allow lateral movement beyond the center 20 ft
- Moistening the precast beams before placement of the CIP deck
- Adding welded wire reinforcement to the longitudinal joint between beams

A new study by the University of Minnesota research team is currently mapping the cracks that have developed. The plan is to revisit four bridges in the spring and summer of 2010 and 2011 and monitor any changes. Based on the findings of this study, the research team should have a better understanding of the nature of the cracks and their effect on durability. They will evaluate the performance of the system and propose final changes to the PCSS standard design and construction details.

Costs

There have been seven new bridges built and one rehabilitated using the PCSS system. Aside from the initial pilot projects, all of the bridges that were constructed showed only a slight incremental cost increase. On average, the cost of using the PCSS system was approximately 10%-15% higher than a comparable CIP slab span bridge. However, the savings in construction time was often substantial. There is potential to shorten construction time by 20% to 40%. Under the correct circumstances, the added cost can be easily justified by the significant construction timesavings. Lengthy road closures or extended construction periods are often very costly to area residents and local businesses, especially in Minnesota's tourist areas. Innovative construction techniques that allow for shorter delays are typically looked upon favorably.

MnDOT's PCSS project has shown that a precast, prestressed concrete superstructure system is an economical and effective practice for rapid bridge construction. The continued development and utilization of rapid construction techniques has the potential to revolutionize bridge construction and MnDOT is planning to use this technique on four more bridges in the near future.

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On Bridge 04002, a precast concrete beam is being moved into place alongside five sections that have already been erected. The typical 6 ft 0 in. beam width can be changed to accommodate bridge width.

At Bridge 66004, a precast concrete beam is lowered onto the substructures. The diamond pattern in the concrete provided a roughened surface to assist with composite action. Presently, a roughened surface is provided on all contact surfaces except the tops of the flanges.

This is Bridge 66004, TH 60 over the Cannon River in southern Minnesota after completion.

Completed Bridge 04002, TH 72 over the Tamarac River in northern Minnesota during the early fall season.