Accelerating Bridge Construction with a Precast Deck System

What Was the Need?
To build bridges more rapidly and reduce the traffic delays, environmental impacts and quality control problems caused by regular construction methods, departments of transportation are increasingly investigating the use of accelerated construction methods that incorporate precast elements.

In 2005, MnDOT developed the Precast Composite Slab Span System (PCSSS), an accelerated bridge superstructure component based on a system used in France. PCSSS bridges consist of adjacent precast beam elements, each shaped like an inverted “T,” that also serve as in-place formwork for a cast-in-place concrete deck. This system eliminates the need for time-consuming construction of deck formwork in the field. The system is designed for bridges with short spans of 20 to 50 feet, which are common in rural areas where bridge closures can result in long detours.

In the past, however, other precast bridge systems have developed cracking on the deck surface above the precast elements. Consequently, MnDOT has conducted pilot projects to help improve the design of these bridges to minimize deck cracking and improve cost-effectiveness and constructability. Between 2005 and 2011, MnDOT constructed 12 bridges using three successive generations of PCSSS design. Research was needed to determine the effectiveness of these designs and make recommendations for further refinements.

What Was Our Goal?
The objective of this investigation was to evaluate the field performance of a sample of PCSSS bridges from three generations of design by conducting detailed crack mapping and core analysis as well as by analyzing strain data from a first-generation bridge instrumented during construction in 2005.

What Did We Do?
For five of the 12 PCSSS bridges, researchers evaluated the effects of design changes by examining core samples and conducting detailed surveys of deck surface cracking. They recorded surface cracking during three inspections between the fall of 2009 and the summer of 2011, using a systematic procedure to map the locations and widths of surface cracks for each bridge.

Researchers extracted core specimens from each of the five inspected bridges where they anticipated reflective cracks and examined them under a digital microscope. They compared the results of this core investigation to the corresponding surface crack maps.

Researchers then evaluated the performance of a PCSSS bridge built in 2005, which was instrumented with strain gages, to investigate the potential for reflective cracking. Researchers also used a parametric study to compare the cost-effectiveness of current continuous system PCSSS designs with simple-span designs. Finally, they reviewed proposed PCSSS design methods and details and provided recommendations for future designs.
What Did We Learn?

Field inspections indicated that with some anomalies, the changes made between each PCSSS design generation improved performance. However, third-generation bridges still had significant issues with cracking, including longitudinal cracking most likely caused by restrained shrinkage between the cast-in-place topping and the precast T-sections. Strain data from the 2005 bridge showed a progression of reflective cracking in two locations and cracking due to thermal restraint near the supports of the continuous spans. Strain data were confirmed by cracks observed in core specimens near the locations of the strain gages.

Computer modeling showed that simple-span PCSSS designs were generally as cost-effective as continuous designs. Spans less than 30 feet were slightly more effective because large strains did not develop. However, spans greater than 30 feet using a continuous design were subject to strains due largely to thermal gradient effects. This effectively negates the intended benefit of continuous designs, which is to increase the capacity of the bridge to withstand live traffic loads.

Researchers offered recommendations for future PCSSS designs, addressing such factors as shrinkage restraint, reflective crack control, composite action and tolerance definitions.

What’s Next?

MnDOT is still working to solve deck cracking issues in PCSSS bridges and currently is limiting their use. It will evaluate the design changes recommended by this study and explore the possibility of further reducing cracking through the use of enhanced concrete deck mixtures.

“Local cities and counties are eager to use PCSSS bridges, so we’re working on enhanced concrete mixtures to reduce the deck cracking that continues to be an issue for these systems.”

—Paul Rowekamp, MnDOT Bridge Standards & Research Engineer

“This system can be a good tool for maintenance engineers replacing approach spans, which can be difficult to cast on-site due to the lack of access for formwork.”

—Cathy French, I.T. Distinguished Professor, University of Minnesota Department of Civil Engineering

For each bridge, researchers created a comprehensive crack map of the bridge deck showing surface cracking in relation to significant structural features and using different line types to distinguish relative crack widths. They compared these maps to cracking in core samples.