Second-Generation, Full-Depth, Precast Concrete Deck System

Nebraska Department of Roads Applies NUDECK to Improve Constructability and Cost-Effectiveness

FOUAD JABER

The author is Assistant State Bridge Engineer, Nebraska Department of Roads, Lincoln.

Full-depth, precast concrete deck systems offer several advantages in bridge construction compared with cast-in-place concrete decks: improved construction quality, reduced construction time, decreased impact on the traveling public, possible weight reduction, and a lower bridge life-cycle cost.

Precast concrete decks are superior in quality to field-cast concrete decks because the production in a controlled plant environment eliminates the variability caused by weather conditions, casting operations, and curing techniques. Moreover, precast concrete decks significantly reduce—if not eliminate—the risk of shrinkage cracking, because the high-performance concrete, the two-way prestressing, and the delaying of the connection to the stiffer girders restrain deck deformation.

Skewed precast concrete deck panel top view, showing the lifting inserts.

PHOTO: NEBRASKA DOR

Problem

Precast concrete deck systems can be designed to be composite or noncomposite with the supporting girders. Although the noncomposite deck is less expensive than a composite deck, the composite design yields a more economical bridge solution with smaller girders and superior structural performance.

Traditional full-depth, composite precast concrete deck systems make use of continuous open channels along the girder lines or of open discrete pockets spaced at a maximum of 2 feet to accommodate the shear connectors that bond the deck to the girder. These channels or pockets are grouted, and the deck surface is overlaid, similar to methods used on cast-in-place deck systems; however, this increases the duration and cost of construction.

In addition, transverse joints in traditional precast concrete deck systems are either conventionally reinforced or are posttensioned with strands threaded through embedded ducts along the bridge's length. The joints or ducts must be specially grouted. These operations complicate the processes of fabrication and erection and consequently reduce the attractiveness of precast concrete deck systems to accelerate construction.

Solution

The research project sought to develop a precast concrete deck system that would address the shortfalls of traditional systems. Table 1 (page 40) presents a side-by-side comparison of the proposed system and traditional full-depth, full-width precast concrete deck systems according to four criteria: panel length, shear connectors, panel penetrations, and longitudinal reinforcement.

The use of longer panels reduces the number of panels, transverse joints, and cast-in-place operations. Increasing the spacing between the shear connectors simplifies the fabrication of both the precast girder and the deck and minimizes conflicts in matching connectors with pockets during erection.

Photo: Nebraska DOR

Skewed precast concrete deck panel: bottom view showing the shear pockets.

In addition, using covered pockets with limited penetration yields a more durable deck surface that does not require an overlay; this reduces life-cycle cost.

Placing posttensioning strands over each girder line before the deck placement simplifies the operation of posttensioning and eliminates the need for threading strands and for grouting the embedded ducts. The goal is to achieve a deck with a service-life expectancy that matches the bridge's design life—75 years, according to the load and resistance factor design manual of the American Association of State Highway and Transportation Officials.

System Refinements

These proposed techniques derived from the experience of the Nebraska Department of Roads (DOR) in constructing Skyline Bridge in Omaha in 2004 using the first generation of a precast concrete deck system called NUDECK. The second generation of NUDECK incorporates several refinements that improve constructability and cost-effectiveness. Table 2 (page 41) shows a comparison between the first and second generations of the NUDECK system.

Several analytical and experimental investigations were conducted at the University of Nebraska–Lincoln to evaluate the new system's structural performance and constructability. These included the fabrication of a 50,000-pound deck panel, 42 feet wide, 12 feet long, and 8 inches thick, to demonstrate production and handling operations (see photos, page 39 and this page).

The panel had three covered shear pockets with 4 feet of spacing along each girder line. Each pocket was made of hollow structural section steel with welded anchor bars and lifting inserts to minimize penetrations of the panel.

Demonstration and Tests

The research project also fabricated a 60-foot-long precast, prestressed concrete I-girder (NU900) with embedded shear connectors (see photo, page 41). These connectors were adjustable in height to ensure adequate embedment in the shear pocket and to compensate for camber variability.

Several pull-out and push-off tests were conducted to evaluate the interface shear capacity of the connections. A complete demonstration of the construction sequence of a 60-foot-long girder and five 12-foot-long deck panels was conducted, including the posttensioning and grouting. Strand deviators similar to those used in draping pretensioning strands were embedded in the girder ends; this raised the posttensioning strands at the top of the girder within the end panels to the middle of the deck and achieved uniform longitudinal prestressing at the deck level. Self-consolidating concrete filled the gap between the girder and deck soffit, as well as the shear pockets. The demonstration can be viewed online.[1]

The demonstration specimen was tested to evaluate the flexural capacity and stiffness of the composite section, as well as the interface shear capacity of the deck-to-girder connection. The test results indicated that the measured capacity of the proposed system exceeded the predicted capacity of a fully composite system. More information is available in the final report.[2] The testing procedure and results also are posted online.[3]

TABLE 1 Proposed and Traditional Precast Concrete Deck Systems: Comparison

Criteria	Traditional Precast Concrete Deck Systems	Proposed System
Panel length	8 ft or less	12 ft
Shear connectors	Either continuous connectors or discrete at a maximum spacing of 2 ft	Discrete connectors at spacing of 4 ft and possibly 6 ft
Panel penetrations	Continuous open channel or open pockets requiring a deck overlay	Covered pockets with grouting ports that do not need an overlay
Longitudinal reinforcement	Conventional reinforcement or posttensioned strands threaded through embedded ducts	Posttensioned strands preplaced in the haunch underneath the deck panels

[1] www.youtube.com/watch?v=Jky8gpaGhRc.
[2] http://ne-ltap.unl.edu/Documents/NDOR/NUDECK%20Implementation%20Final%20Report.pdf.
[3] www.youtube.com/watch?v=8Fja_facav8.

Application

Nebraska DOR is implementing the second generation of the precast concrete deck system NUDECK in the construction of the Kearney East Bypass over US-30 and the Union Pacific Rail Road. Construction started in the summer of 2014 and is slated to end in fall 2015.

The project consists of twin bridges: the southbound bridge is to be constructed with a conventional cast-in-place deck, and the northbound bridge with the new precast concrete deck system. This will allow a comparison of the construction and long-term performance of the two bridges in the same environment.

Each bridge has a two-span continuous deck, 41 feet and 8 inches wide and 332 feet long, supported by 10 prestressed concrete girders (NU1800) with 8 feet and 6 inches spacing. The precast concrete deck is 8 inches thick and consists of 28 panels. An online animation presents the construction sequence of the bridge superstructure in detail.[4]

Benefits

Although the benefits of the proposed precast concrete deck system cannot be quantified yet in terms of the quality, economy, speed, and safety of the construction, the experience of producing and erecting a full-scale specimen has identified potential benefits. Precast concrete deck panels can be produced easily with 6,000-pounds-force-per-square-inch, high-performance concrete that is cured properly and uniformly; this is difficult to achieve with cast-in-place decks. The proposed deck-and-girder detailing is production friendly, eliminating the projection of bars or inserts, which require special forming; moreover, the detailing follows standard production practices.

The cost of the shear pockets and shear connectors ranges from $2.50 to $3.50 per square foot of deck surface, depending on the girder spacing. The cost of the proposed posttensioning system ranges from $2 to $4 per square foot of deck surface, depending on the bridge length and girder spacing.

In addition, the use of self-consolidating concrete instead of commercial grout to fill the pockets and haunch is expected to improve the economy of the system. The new method is expected to be competitive with cast-in-place deck construction.

For more information, contact Fouad Jaber, Assistant State Bridge Engineer, Nebraska Department of Roads, 1500 Highway 2, P.O. Box 94759, Lincoln, NE 68509-4759; 402-479-3967; or Fouad.Jaber@nebraska.gov.

Editor's Note: Appreciation is expressed to Waseem Dekelbab, Transportation Research Board, for his efforts in developing this article.

[4] www.youtube.com/watch?v=FOqcmkik_4Y.

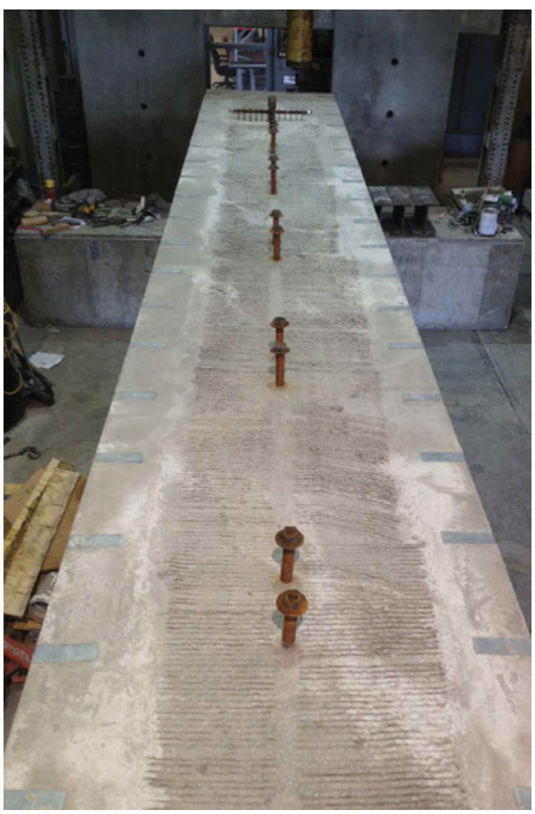
Photo: Nebraska DOR

Top view of the precast–prestressed concrete I-girder showing the shear connectors.

TABLE 2 First and Second Generations of NUDECK Systems: Comparison

Item	First Generation	Second Generation
Panel length	8 ft	12 ft
Panel thickness	6 in. plus 2 in. Type K cement overlay	8 in. without overlay
Panel–girder connection	12-in.-wide, continuous open channel on top of each girder line, to be filled with conventional concrete	16- x 8- x 5-1/2-in. covered individual pockets at 4-ft spacing, with grouting holes to be filled with self-consolidating concrete
Shear connectors	1.25-in.-diameter studs at 6 in. spacing	Two 1.25-in.-diameter coil rods at 4 ft spacing
Transverse pretension	Four 0.5-in.- (top) and four 0.5-in.-diameter (bottom) strands at 24 in. spacing	Six 0.6-in.- (top) and six 0.5-in.-diameter (bottom) strands at 2 ft spacing
Longitudinal posttension	0.6-in.-diameter strands threaded through the open channel at deck midthickness	0.6-in.-diameter strands laid down at the haunch area below the deck panels

Suggestions for Research Pays Off topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2956; gjayaprakash@nas.edu).