Composite Girder Connections for Precast Concrete Decks

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Installed precast concrete deck panels with pockets and beams with shear connectors. Photo: Purcell Associates.

The shear connection between precast composite concrete bridge decks and girders is receiving renewed attention as precast concrete deck panels have become an alternative to cast-in-place decks in accelerated bridge construction. Shear connections are commonly made in precast concrete deck panels by using steel connectors, such as studs or bars. The steel connectors extend from the top of the girder into blockouts in the panel, which are then grouted. However, the maximum connector spacing limit of 24 in., defined in the *AASHTO LRFD Design Specifications*, poses a dilemma for precast concrete deck design. There are two important reasons why closely spaced blockouts are undesirable in precast concrete deck panels. First, each blockout requires special labor for grouting. Second, a precast concrete deck panel manufactured with blockouts spaced at 24 in. may have a definite plane of weakness through the blockout openings. Special care must be taken to reinforce this weak section, particularly for effects of moving and handling to avoid cracking. In both cases, minimizing the number of connectors and blockouts is preferred.

The original sources of the current maximum connector spacing of 24 in. are unclear. An investigation described in *NCHRP Report 584*,[1] on full-depth precast concrete deck panels, attributes that limit to a "rule of thumb" in design suggested in 1943 by Newmark and Siess.[2] The 24-in. limit first appeared in the 4th edition of the *AASHTO Standard Specifications for Highway Bridges* in 1944.

These connections using studs were the focus of a push-off investigation by Issa[3] in which clusters of studs in a pocket were found to have less capacity than the sum of individual studs. The AASHTO Q_n capacity value for studs in Article 6.10.10.4 of the *2012 AASHTO LRFD Specifications*, however, matched Issa's measured capacity for two stud clusters in a single pocket. The test data showed a 15 to 25% capacity reduction when the number of studs was increased or the number of pockets increased. AASHTO does not specifically change capacity with the number of studs in a cluster, but taking the capacity as 85% or less of AASHTO's value when more than two studs are clustered in a pocket is recommended based on Issa's work.

Three threaded-rod shear connectors extending from the girder will be grouted into the blockout in the Texas Department of Transportation deck panel. Photo: TxDOT.

A series of recent research activities has re-examined the needs of composite deck connections. Testing of panels connected to 84-ft-long steel girders with both 24-in. and 48-in. connector spacing was conducted at the University of Wisconsin and found no reduction in composite action stiffness or strength with the wider spacing, even after 2 million cycles of repeated service loading. On testing to the theoretical ultimate capacity, no deck uplift was detected and the 48-in. connector spacing provided an actual ultimate load capacity higher than predicted using AASHTO procedures, even though no capacity reduction was taken for multiple studs per pocket.

Additional work described in the *NCHRP Report 584* resulted in suggested guidelines for designing deck panels with wider connection spacings. These research activities were followed by the construction of two bridges using 48-in. spacing for the connectors.

The Live Oak Creek Bridge built by the Texas Department of Transportation (TxDOT) in 2008 used 8-ft-wide by 32-ft-long precast concrete, 8-in.-thick deck panels on precast concrete I-girders. The shear connections were spaced at 48 in. and used three 1¼-in.-diameter steel rods, in a group, extending from the girder into blockouts of the deck panels. This bridge has been reported by TxDOT as performing very well.

Wisconsin also used precast concrete deck panels with 48-in. connector spacing in the widening and redecking of a heavily traveled bridge on Interstate 39/90. The panels were 8-in. thick with rectangular blockouts into which clusters of 6- to 10$^{7}/_{8}$-in.-diameter headed studs from the steel girders were embedded and grouted. No capacity reduction was used for the large stud clusters. The Wisconsin bridge was built in 2006 and averages 60,000 vehicles per day. Inspections have found that the precast concrete deck, on one of a pair of bridges, appears to be performing better than the cast-in-place concrete deck on the twin bridge.

Interstate I-39/90 deck with studs in pockets at 48-in. spacing. Photo: University of Wisconsin.

A wider spacing than 24 in. for the composite connections between precast concrete deck panels and bridge girders appears appropriate. Forty-eight-inch spacings were successfully implemented in these recent research and construction projects. Recent research has not, however, examined the behavior of composite decks with shallow beams. As the beam becomes

Wisconsin laboratory test beam for fatigue cycling. Photo: University of Wisconsin.

shallow relative to the deck, the system with 48-in. spacing acts less like a composite beam and more like a Vierendeel truss. With shallow beams we suggest that the composite connector spacing be limited to a maximum distance equal to the beam depth.

At its 2013 annual meeting, the AASHTO Highway Subcommittee on Bridges and Structures approved a change to Article 5.8.4.2 of the *LRFD Bridge Design Specifications* to permit a longitudinal spacing up to 48 in. but not greater than the beam depth. This change will become effective with the 2014 Interim Revisions.

Care should be taken, however, when large clusters of studs are used, as required by wider spacings. Confinement from reinforcement should be provided around the stud pockets and spacings greater than 48 in. are not suggested. A stud capacity reduction of 25% may be reasonable for design, with multiple studs per pocket, based on the work of Issa. A

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References

1. *Badei, S., and M. Tadros. 2007. "Full Depth Precast Concrete Bridge Deck Panel Systems." NCHRP Report 584, Transportation Research Board, Washington D.C. (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_548.pdf).*
2. *Newmark, N. M., and C. P. Siess. 1943. "Design of Slab and Stringer Highway Bridges."* Public Roads, *FHWA, Washington, D.C. Vol. 23, No. 1.*
3. *Issa, M.A., T. Patton, H. Abdalla, A. Yousif, and M. Issa. 2003. "Composite Behavior of Shear Connectors in Full-Depth Precast Concrete Bridge Deck Panels on Steel Stringers."* PCI Journal, *PCI, Chicago, Ill. Vol. 48, No. 5 (Sept.-Oct.).*

EDITOR'S NOTE

More information about composite girder connection for precast decks is available as follows:

- *Carter, J., F. Hubbard, M. Oliva, T. Pilgrim, and T. Poehnelt. 2007. "Wisconsin's Use of Full-Depth Precast Concrete Deck Panels Keeps Interstate 90 Open to Traffic."* PCI Journal, *PCI, Chicago, Ill. Vol. 52, No. 1 (Jan.-Feb.).*
- *Markowski, S.M., et al. 2005. "Full Depth Precast Prestressed Bridge Deck Panel System for Bridge Construction in Wisconsin," Proceedings from the PCI National Bridge Conference, PCI, Chicago, Ill.*
- *PCI Committee on Bridges.* State-of-the-Art Report on Full Depth Precast Concrete Bridge Deck Panels, *PCI, Chicago, Ill. SOA-01-1911.*