Precast, Prestressed Concrete Bent Caps: A Faster, Safer, and More Durable Alternative

by Christopher P. Miller, Texas Department of Transportation

The Texas Department of Transportation (TxDOT) has been developing and implementing prestressed, precast concrete bent caps (PPBC) as an efficient, durable, and safe alternative to conventionally reinforced cast-in-place (CIP) concrete bent caps.

Construction Projects

TxDOT first used PPBCs in 2014, on a project located in Bexar County on Texas State Highway Loop 1604. In this project, twin-bridge structures, approximately 2100 ft in length, contained 36 bent caps designed with the same dimensions and reinforcement. The original design called for CIP bents, but the contractor requested post-letting to add a precast concrete option to help reduce construction time. Because of the similarity of the bents, the fabricator could cast them rapidly. Once installation of the PPBCs began, it took only three days to install all of the caps for one of the bridges.

PPBCs were also used for an emergency project to replace a bridge on Fischer Store Road in Hays County that washed out in a major flood event in 2015. For this project, PPBCs were included in the original plan set as an alternative to CIP bent caps. The contractor elected to use PPBCs to expedite construction. Reopening the bridge quickly was important because the nearest detour added nearly an hour to commuters' drives. The contractor installed all of the PPBCs in one day, and the overall bridge was completed in 80 days, opening to traffic in February 2016.

Design

The design philosophy for the initial PPBCs was to match or exceed the ultimate moment and shear capacities of the original CIP design. In Texas, CIP bent caps are designed with Grade 60 reinforcing steel and TxDOT's Class C concrete with a compressive strength of 3.6 ksi. PPBCs are designed with Grade 270, low-relaxation, 0.6-in.-diameter prestressing strands and TxDOT's Class H concrete. The compressive strength of Class H concrete can range from 5 to 8.5 ksi, depending on what is specified in the plans.

The number of strands was selected based on the moment demand, and the strands were placed symmetrically in the cap so that there would be no camber. The transverse reinforcement in PPBCs was designed to match the shear reinforcement in the CIP caps and to provide sufficient resistance to bursting stresses at the cap ends. Because the compressive strength of Class H concrete is higher than that of Class C concrete, the shear capacity of the PPBCs exceeds the shear capacity of the CIP caps with the same transverse reinforcement. Once moment and shear designs were completed, stress checks were performed at different loading situations, including casting yard, transportation/lifting, and service load, to ensure that the caps will not crack.

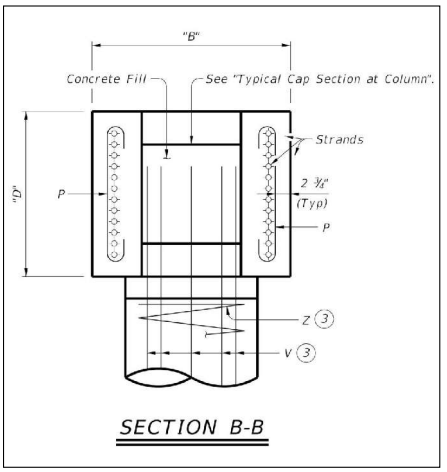
TxDOT PPBC Standard

To date, each PPBC project by TxDOT has been a custom design. In an effort to increase the use of PPBCs, TxDOT published a PPBC standard[1] for use with round columns in April 2017. This standard provides PPBC designs for use as an alternative to TxDOT's standard CIP bent caps. The PPBC standard provides details to support the following TxDOT beam types: TxGirder, box beam, slab beam, decked slab beam, and spread slab beam. These standards account for nearly 2000 different bridge configurations and can be found on the TxDOT Bridge Standards web page.

The design philosophy for the PPBC standard varies slightly from the previous custom designs. Instead of designing the caps to have equal or greater capacities than their CIP versions, the standard PPBC designs are based on the loading from the superstructure. The number of strands and the amount of transverse reinforcement are optimized, and a single design is provided for each different beam type.

Another difference from the earlier designs is the column connection details. The earlier PPBCs were connected to the column

Prestressed, precast concrete bent caps at northbound loop of Texas State Highway 1604. Prior to grouting the column connection, precast concrete caps are supported on shim packs placed on the top of each column. Photo: Texas Department of Transportation.



Cross section of prestressed, precast concrete bent cap at column cap pocket connection.[1] Figure: Texas Department of Transportation.

using grouted vertical ducts. In this older-style connection, column reinforcement was terminated at the top of the column, and dowels extended from the top of the column through vertical ducts that were cast into the PPBC. Once the PPBC was placed on the columns, the ducts were grouted to complete the connection. In the TxDOT standard, the connection has been changed to a cap pocket. In the cap pocket connection, the column reinforcement is extended into a pocket in the PPBC that is formed with a corrugated metal pipe. Once the PPBC has been placed, the pocket is filled with TxDOT Class C or Class S concrete. This change was made so that connecting the cap to the columns would be simpler.

Research

In 2015, TxDOT sponsored a research project to develop standardized details for PPBCs and verify their performance compared with conventional CIP caps. The project tested full-scale PPBCs and CIP caps to compare performance at load levels up to and including failure. It also experimented with different reinforcing steel and connection details to improve structural performance and make construction easier. The final report on the project, which ended in November 2017, has not yet been published. Moving ahead, TxDOT intends to implement findings from research and construction projects and increase the use of PPBCs in bridge projects.

Prestressed, precast concrete bent caps (PPBCs) at Fischer Store Road in Hays County. The contractor installed all of the PPBCs in one day. Photo: Texas Department of Transportation.

Reference

1. Texas Department of Transportation. 2017. Prestressed, Precast Bent Cap Option for Round Columns (PPBC-RC). ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/bridge/ppbcstd1-17.pdf.

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