U-Girder Standards Upgraded for External Post-Tensioning Tendons

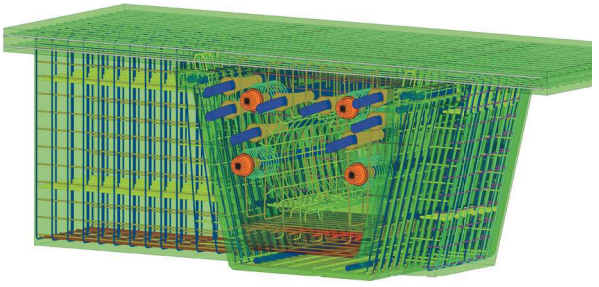
New Go By sheets/concept drawings for curved, precast concrete spliced U-girders using bonded and unbonded post-tensioning for the next generation of structures

by Sam Fallaha, Florida Department of Transportation, and William N. Nickas, Precast/Prestressed Concrete Institute

Recent changes to Florida Department of Transportation's (FDOT's) post-tensioning policy that requires replaceable tendons have led to revisions of standard practices for post-tensioning bridge structures. With the growing popularity of curved, precast concrete spliced U-girders, engineers saw a need to update and upgrade the existing Precast/Prestressed Concrete Institute (PCI) Zone 6 U-girder designs to meet the new requirements. The result was a new set of concept drawings for spliced U-girders that use replaceable external tendons.

FDOT has taken a new look at the system that started in Colorado and was promulgated to the East coast by PCI. The latest concepts, which were approved by the Federal Highway Administration in July, were announced in FDOT *Structures Design Bulletin 17-08*, which can be found at www.fdot.gov/design/bulletins/SDB17-08.pdf. In an earlier memorandum, FDOT *Structures Design Bulletin 15-01*, FDOT instituted a policy that profiled tendons must be replaceable, so these tendons must be filled with flexible filler; however, flat tendons can still be filled with cementitious grout.

The revised PCI Zone 6 U-girder concept plans were developed as a joint effort between PCI and the Florida Prestressed Concrete Association (FPCA), the local PCI Chapter, to create standardized dimensions for curved, precast concrete spliced U-girders that allow access and replacement of external tendons during the service life of the structure. FPCA supported a team of consultants experienced with the system who developed the new concepts; their findings were presented to FDOT in 2016 for review. (For a list of those participating in the study, see the sidebar.)



Example of reinforcement, tendon, and anchorage details for pier diaphragm. All Drawings: Precast/Prestressed Concrete Institute and Florida Department of Transportation.

In addition to meeting FDOT's requirements for replaceable tendons, the new concept drawings (listed below) were also intended to establish a set of standardized sections that could

INDEX OF DRAWINGS

FDOT WU-0	INDEX OF DRAWINGS
FDOT WU-1	GENERAL NOTES
FDOT WU-2	TYPICAL BRIDGE CROSS SECTIONS
FDOT WU-3	END DIAPHRAGM AT ABUTMENT
FDOT WU-4	TYPICAL EXPANSION PIER
FDOT WU-5	TYPICAL INTERIOR PIER WITH BEARINGS
FDOT WU-6	TYPICAL INTEGRAL INTERIOR PIER
FDOT WU-7	GIRDER DIMENSIONS AND REINFORCEMENT
FDOT WU-8	GIRDER SEGMENT LAYOUT 1 - SIMPLE SPAN
FDOT WU-9	GIRDER SEGMENT LAYOUT 2 - CONSTANT DEPTH CONTINUOUS
FDOT WU-10	GIRDER SEGMENT LAYOUT 3 - HAUNCHED CONTINUOUS
FDOT WU-11	COMPARATIVE POST-TENSIONING LAYOUT SCHEMATICS
FDOT WU-12	POST-TENSIONING LAYOUT 1 - PASS THRU OPTION
FDOT WU-13	POST-TENSIONING LAYOUT 2 - LACED OPTION
FDOT WU-14	GIRDER POST-TENSIONING DETAILS 1
FDOT WU-15	GIRDER POST-TENSIONING DETAILS 2
FDOT WU-16	STRESSING CHAMBER DETAILS
FDOT WU-17	CONSTRUCTION SEQUENCE 1 - SIMPLE SPAN
FDOT WU-18	CONSTRUCTION SEQUENCE 2 - CONSTANT DEPTH GIRDER
FDOT WU-19	CONSTRUCTION SEQUENCE 3 - HAUNCHED GIRDER
FDOT WU-20	ERECTION BRACING
FDOT WU-21	EXAMPLE ERECTION PLAN DETAILS

Index of FDOT curved, precast concrete spliced U-girder drawings (Drawing WU-0).

Study Participants

The team participating in the FPCA-PCI study on wax-filled tendons for curved, spliced U-girders comprised:

Bob Anderson, AECOM (formerly URS), Tampa, Fla.

Roger Becker, PCI, Chicago, Ill.

John Corven, Corven Engineering, Tallahassee, Fla.

John Crigler, VStructural LLC, Baltimore, Md.

Kent Fuller, Dura-Stress Inc., Leesburg, Fla.

Trevor Kilpatrick, AECOM (formerly URS), Tampa, Fla.

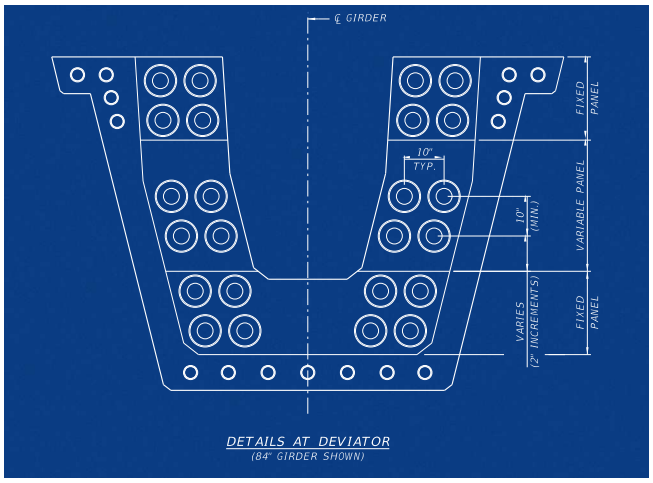
Mason H. Lampton, Standard Concrete Products, Columbus, Ga.

Tom Newton, Gate Precast, Jacksonville, Fla.

William N. Nickas, PCI, Chicago, Ill.

Richard Potts, Standard Concrete Products, Savannah, Ga.

Dr. Audi Sriboonlue, Dura-Stress Inc., Leesburg, Fla.



U-girder post-tensioning details—Typical deviator locations (Drawing WU-14).

be produced cost-effectively. By using a uniform deviator design at a consistent spacing, the existing outer-formwork systems were preserved and could be used to satisfy the particular requirements of a project. With external tendons, the web thickness could be decreased, resulting in girder weights (including deviators) similar to those from the original PCI Zone 6 sections with internal tendons. The new concept drawings can be found at http://www.fdot.gov/structures/innovation/UBEAM.shtm.

The team, along with other industry experts, passionately discussed the changes in details, including the new system's reduced tendon eccentricities that have a significant impact on the efficiency of the structure. Once several projects have been specified and bid, contractors and designers can evaluate the costs of the increased post-tensioning quantities compared to thinner webs and simpler splice details (fewer ducts across the closure pours). It is anticipated that the cost of the new system with thinner webs, external tendons, and standardized deviators will be similar to the cost of the old system with internal grouted tendons.

U-Girder Advantages

Advantages identified by FDOT for the use of curved, precast concrete spliced U-girders include reduced fabrication times, faster construction, longer spans, and increased aesthetic appeal. Important considerations that need to be made before using this type of construction include shoring requirements, equipment selection for lifting heavy girder sections, field and erection engineering, and monitoring settlement and movement of temporary foundations during erection and post-tensioning operations. (For more on the development and early use of curved, spliced U-girders, see the Creative Concrete Construction article "Curved, Spliced, U-Girders Gain Momentum" in the Fall 2012 issue of *ASPIRE*℠.)

Design Criteria Update

Additional design criteria are included in FDOT's recent bulletin announcing the new precast concrete spliced U-girder concept drawings. A new limit state for the design of pretensioned/post-tensioned I-beams and U-girders is implemented, along with direction to use strain compatibility to determine section capacities. The purpose of the new limit state is to provide assurance that the structure has sufficient capacity in the event of failure of grouted tendons. The use of strain compatibility ensures accurate accounting of the controlling strains at any section and also accounts for the difference between unbonded steel, where the strains are constant over the length of the tendon, compared with bonded steel, where the strains vary along the length of the tendons. The use of strain compatibility assures accurate accounting of the controlling strains at any section. The additions to the FDOT *Structures Design Guidelines* are as follows:

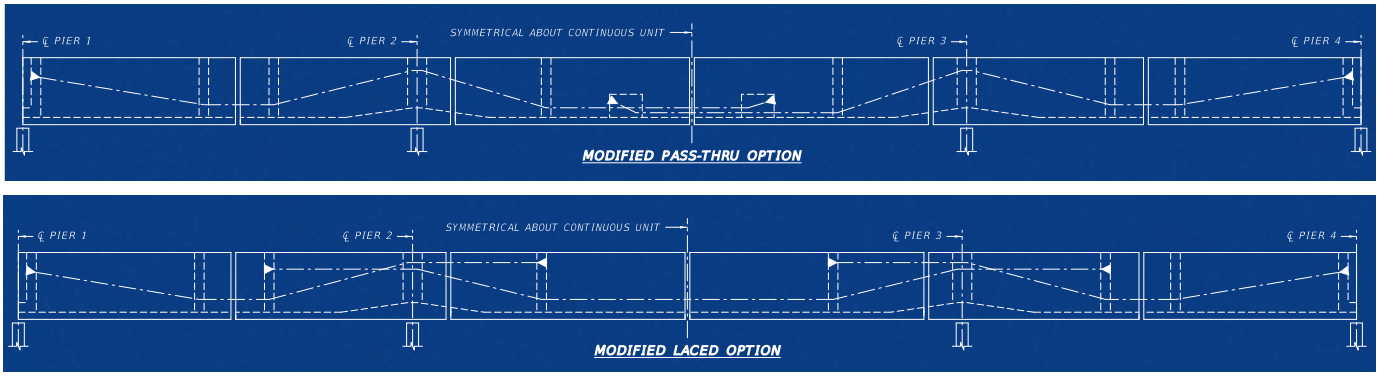
- For pretensioned/post-tensioned I-beams and U-girders, in addition to the load combinations required by American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*,[1] satisfy the following limit state neglecting strand tendons that are grouted with cementitious material:

  $$1.25(D) + 1.75(LL) \leq 1.4(RN^*)$$

  where
  - D = all applicable permanent load components of LRFD[1] Table 3.4.1-1
  - LL = all applicable transient load components of LRFD[1] Table 3.4.1-1
  - RN^* = nominal capacity (moment or shear) at any section using only the replaceable strand tendons with flexible filler, all permanent bar tendons, mild reinforcing steel, and pretensioning strands
- Use strain compatibility to determine section capacities using bonded and unbonded post-tensioning tendons, mild reinforcing steel, and pretensioning strands.

Benefits of Go By Sheets

The concept drawings show standardized positions of external tendons in the diabolos (uniquely shaped voids designed



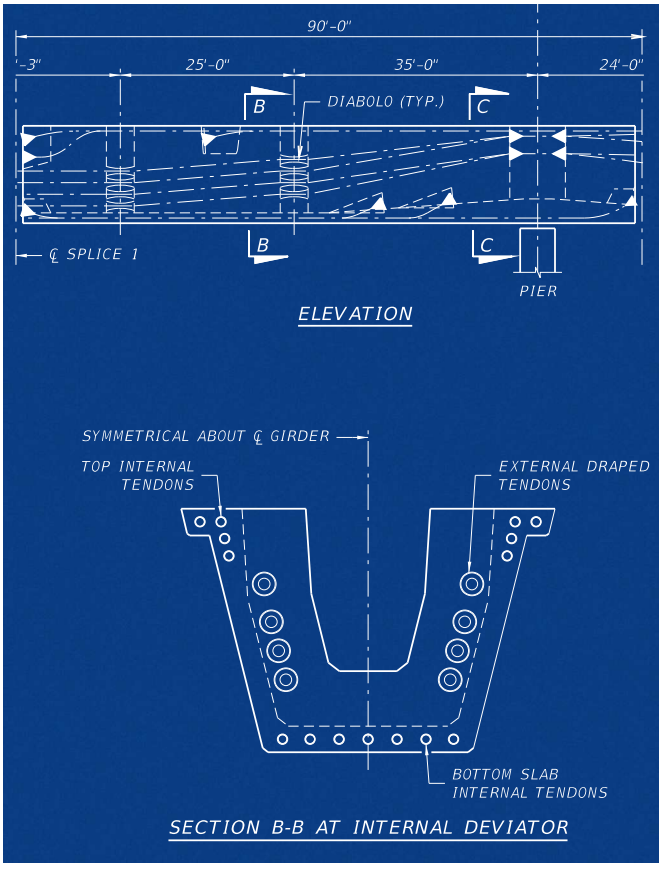
Two post-tensioning layout schematics (Drawing WU-11).

and formed into concrete deviator segments in a shape that accommodates the angle change of the tendon through the deviator. See "External Tendons with Diabolos—Making Something Out of Nothing," Fall 2015 *ASPIRE*), which offer significant cost savings in forming systems. When horizontal adjustments of tendon locations are needed in the midheight region, a variable-panel detail can be used. The absolute minimum centerline-to-centerline distance of the diabolos is 10 in. both vertically and horizontally for 19-strand tendons.

Drawing WU-11(excerpt shown on previous page) shows several options for tendon layouts. The pass-thru layout is typical of current construction, but with replaceable tendons, an end chamber would be required to allow access to the tendons for replacement. Eliminating end chambers at the supports by using laced and modified-laced tendons that are stressed at anchorages within the girders will avoid wide piers and costly substructure features. The drawing shows anchorage locations for both pass-thru and laced tendon layout.

Replaceable external tendons and internal stranded post-tensioning tendons are used for analysis at the service limit state. All tendons in the U-beam will be counted on for the ultimate limit strength requirements, with bonded PT bars allowed at all limit states.

For states not implementing replaceable tendons with flexible filler, this standardized solution could be used with grouted external tendons, the conventional approach that the concrete segmental industry uses worldwide.



Exerpt from post-tensioning layout 1—Pass-thru option (Drawing WU-12).

Summary

The additional design criteria in FDOT *Structures Design Bulletin 17-08* and the curved, precast concrete spliced U-girder concept drawings came about due to the focused and persistent efforts of industry, FPCA, and FDOT staff to create a collaborative solution that could meet the goals of each stakeholder. It is imperative that designers be provided successful concepts of the new generation of curved, precast concrete post-tensioned structures with replacable tendons and optimize them to meet the requirements of the owner.

Reference

1. AASHTO (American Association of State Highway and Transportation Officials). 2015. *AASHTO LRFD Bridge Design Specifications*. 7th ed. Washington, DC: AASHTO.

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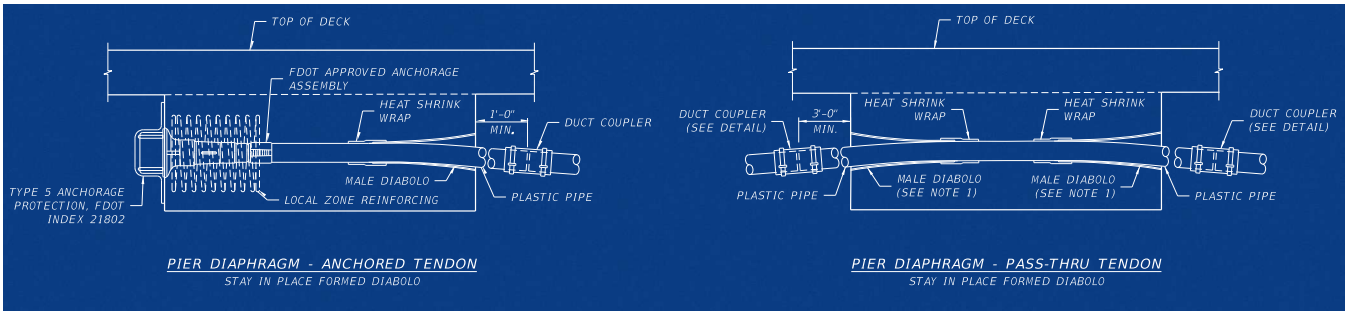
EDITOR'S NOTE

While the revisions to the PCI Zone 6 U-girder details discussed in this article were made to address FDOT's use of wax-filled external tendons, the concepts and details can also be used with grouted external tendons that have been successfully used around the world. The full set of drawings is available at www. aspirebridge.org or www. fdot.gov/design.



Typical diabolo details (Drawing WU-15).