Florida Department of Transportation

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STRUCTURES DESIGN BULLETIN 13-07

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TO: District Directors of Operations, District Directors of Production, District Design Engineers, District Construction Engineers, District Structures Design Engineers, District Professional Services Administrators

FROM: Robert V. Robertson, P. E., State Structures Design Engineer

COPIES: Tom Byron, Brian Blanchard, Duane Brautigam, David Sadler, Rudy Powell, Charles Boyd, Jeffrey Ger (FHWA)

SUBJECT: Spliced Pretensioned/Post-Tensioned U-Girders

This ***Structures Design Bulletin*** introduces requirements for the design and detailing of Spliced Pretensioned/Post-Tensioned U-Girder bridges. This bulletin also includes other changes to the ***Structures Design Guidelines*** that are necessary to differentiate between Spliced Pretensioned/Post-Tensioned U-girder bridges and other superstructure types.

REQUIREMENTS

1. Add the following paragraph to ***Structures Design Guidelines*** Section 4.1.3:

A. Size precast sections of horizontally curved spliced U-girders such that the total hauling width does not exceed 16 feet.

2. Replace ***Structures Design Guidelines*** Table 4.5.5-1 with the following:

Table 4.5.5-1 Minimum Center-to-Center Longitudinal Duct Spacing

Post Tensioned Bridge Type	Minimum Center To Center Longitudinal Duct Spacing [1]
Precast and CIP Segmental Balanced Cantilever Bridges	8-inches, 2 times outer duct diameter, or outer duct diameter plus 4½-inches whichever is greater.
Post-Tensioned I-Girder and U-Girder Bridges	4-inches, outer duct diameter plus 1.5 times maximum aggregate size, or outer duct diameter plus 2-inches whichever is greater (measured along the slope of webs or flanges).
CIP Voided Slab Bridges CIP Multi-Cell Bridges	When all ducts are in a vertical plane, 4-inches, outer duct diameter plus 1.5 times maximum aggregate size, or outer duct diameter plus 2-inches whichever is greater. For two or more ducts set side-by-side, outer duct diameter plus 3-inches. [2]

1. Bundled ducts are not allowed.
2. The 3-inch measurement must be measured in a horizontal plane.

3. Replace ***Structures Design Guidelines*** Table 4.5.5-3 with the following:

Table 4.5.5-3 Minimum Number of Tendons Required for Critical Post-Tensioned Elements

Post-Tensioned Bridge Element	Minimum Number of Tendons
Mid Span Closure Pour CIP and Precast Balanced Cantilever Bridges	Bottom slab – two tendons per web Top slab – One tendon per web (4 - 0.6-inch dia. min.)
Span by Span Segmental	Four tendons per web
CIP Multi-Cell Bridges and Post-Tensioned U-Girder Bridges [1]	Three tendons per web
Post-Tensioned I-Girder Bridges [2]	Three tendons per girder
Unit End Spans CIP and Precast Balanced Cantilever Bridges	Three tendons per web
Diaphragms - Vertically Post-Tensioned	Six tendons if strength is provided by PT only; Four tendons if strength is provided by combination of PT and mild reinforcing
Diaphragms - Vertically Post-Tensioned	Four Bars per face, per cell
Segment - Vertically Post-Tensioned	Two Bars per web

1. Two U-Girders minimum per span.
2. Three girders minimum per span.

4. Replace ***Structures Design Guidelines*** Table 4.5.6-1 with the following:

Table 4.5.6-1 Dimensions for sections containing Post-Tensioning tendons

Post Tensioned Bridge Element	Minimum Dimension
Webs; I-Girder and U-Girder Bridges	8-inches thick or outer duct diameter plus 2 x cover [1] plus 2 x stirrup dimension (deformed bar diameter); whichever is greater.
End Blocks; I-Girder Bridges	Length (including transition) not less than 1.5 x depth of girder
Regions of Slabs without longitudinal tendons	8-inches thick, or as required to accommodate grinding, concrete covers, transverse and adjacent longitudinal PT ducts and top and bottom mild reinforcing mats, with allowance for construction tolerances whichever is greater.
Regions of slabs containing longitudinal internal tendons	9-inches thick, or as required to accommodate grinding, concrete covers, transverse and longitudinal PT ducts and top and bottom mild reinforcing mats, with allowance for construction tolerances whichever is greater.
Clear Distance Between Circular Voids CIP Voided Slab Bridges	Outer duct diameter plus 2 x cover plus 2 x stirrup dimension (deformed bar diameter); or outer duct diameter plus vertical reinforcing plus concrete cover; whichever is greater.
Segment Pier Diaphragms containing external post-tensioning	4 feet thick. [2]
Webs of CIP boxes with internal tendons	For single column of ducts: 12-inches thick. For two or more ducts set side by side: Web thickness must be sufficient to accommodate concrete covers, longitudinal PT ducts, 3-inch min. spacing between ducts, vertical reinforcing, with allowance for construction tolerances. [3]

1. 1" cover minimum at top of web where a deck will be cast over the beam.
2. Post-Tensioned pier segment halves are acceptable.
3. The 3 -inch measurement must be measured in a horizontal plane.

5. Replace the title of ***Structures Design Guidelines*** Section 4.6 with the following:

4.6 SEGMENTAL BOX GIRDERS

6. Replace the title of ***Structures Design Guidelines*** Section 4.7 with the following:

4.7 SPLICED PRETENSIONED/POST-TENSIONED I-BEAMS

7. Add the following new section to the ***Structures Design Guidelines***:

4.8 SPLICED PRETENSIONED/POST-TENSIONED U-GIRDERS

A. Spliced pretensioned/post-tensioned U-Girder bridges, whether curved or straight, with full span or spliced girders, are inherently complex to design and build. They require a coordinated effort between designers and detailers in order to develop integrated plans that address all design, detailing and constructability issues. The information contained herein is only part of the requirements necessary to successfully accomplish this task.

Commentary: Spliced pretensioned/post-tensioned U-girders are primarily intended for use on sharply curved bridges in lieu of steel or concrete segmental box girders. In order to facilitate longer spans, they can also be used on straight or slightly curved bridges in lieu of steel or other concrete girders, or ***Design Standards****, Index 20200 Series prestressed concrete U-beams. However, due to the inherent complexity of designing and constructing spliced pretensioned/post-tensioned U-girders, the use of* ***Design Standards****, Index 20200 Series prestressed concrete U-beams is preferred where possible if a multi-box superstructure is to be used.*

4.8.1 General

A. The minimum section depth for post-tensioned U-girders is 72”. To optimize U-girder formwork standardization and utilization, consider using the 72", 84" and 96" U-girders developed by PCI.

B. Develop haunched girder sections by maintaining the outside shape and dimensions of a typical U-girder and thickening the bottom slab internally, or by deepening a typical U-girder (longitudinally sloping the bottom of the bottom flange) while maintaining the side slope of the webs. The minimum bottom flange clear width within a haunched section is 2’-0” measured along the top of the bottom flange between inside corner chamfers. For haunched girders, the use of an internal, mildly reinforced, secondary cast bottom flange build-up is permitted provided that the secondary cast concrete is made composite with bottom flange using mechanical reinforcing through the interface. Evaluate effects of differential shrinkage between such a build-up and the girder and specify the use of shrinkage reducing admixtures for the build-up concrete as required.

C. A minimum of two girder lines is required.

D. Cast-in-place lid slabs are required for all curved structures; precast lid slabs are not permitted. Lid slabs are to be constructed only after the girder sections are erected and typically before the continuity post-tensioning is applied. Design open girder sections for torsional stresses.

E. Maximum stress in the longitudinal mild reinforcing steel in the deck is limited to 24 ksi.

F. Minimum horizontal radius of a curved U-girder is 500 feet (measured along centerline girder).

G. For horizontally curved U-girders, include additional non-composite dead load on the individual precast U-girder sections to account for the variable web thickness along the length of the girder section.

Commentary: Typical forming techniques that are used for casting horizontally curved U-girder sections include the use of curved forms for the outer surfaces of the webs and chorded straight form sections for the inner surfaces of webs. This forming technique creates variable thickness webs with the thinnest dimension matching the plan dimension and the thickest dimension being slightly larger than the plan dimension. This variable web thickness is not to be included in the U-girder section properties but must be accounted for in the self weight of the girder.

H. Minimum length of closure pours between adjacent U-girder sections is 2'-0".

I. Include the necessary plan notes and details to address construction issues associated with geometry control including provisions for providing a settlement monitoring program of the temporary towers and the ability to make field adjustments to the U-girder sections prior to post-tensioning by jacking, etc.

J. List on the plans the assumed construction live load, weight of screed machine and weight of formwork used for the constructability limit state checks.

K. Include the necessary plan notes and details to address all the other construction issues listed in, or associated with, the above requirements.

4.8.2 Access and Maintenance

During preliminary engineering and when determining structure configuration give utmost consideration to accessibility and to the safety of bridge inspectors and maintenance. Design post-tensioned U-girders for the following special requirements for inspection and access. Precast, pretensioned (non-post-tensioned) U-girders are exempt from these requirements.

A. Utilities and longitudinal or vertical conveyance drain pipes are not permitted inside U-girders. Where possible, locate drainage inlets adjacent to piers and place associated vertical drain pipes outside of U-girders. Utilize external concrete bump-outs or shrouds to conceal pipes as required. See ***SDM*** Chapter 22 for Pier Drainage Details.

B. Electrical:

1. Provide interior lighting and electrical outlets at all ingress/egress access openings and at midspan of each span. Only a single interior light and electrical outlet are required if these locations coincide.
2. Specify in the plans that all electrical and lighting components shall meet the material requirements of ***Design Standards*** Index 21240.

C. Access:

1. Provide a 36 inch minimum diameter access opening through all interior diaphragms. Indicate on plans that diaphragm access openings are to remain clear and are not to be used for utilities, drain pipes, conduits or other attachments. If these items are required, provide additional areas or openings. Provide round or square doors at diaphragm access openings at expansion joints. Design doors to be in-swinging, hinged, galvanized steel screen doors with 0.25-inch mesh galvanized steel screen.
2. Provide either 36 inch minimum diameter or 24" by 42" oblong ingress/egress openings placed in the bottom flange of U-girders. Provide in-swinging, hinged, solid galvanized steel doors and steel hardware at all ingress/egress openings.
3. Equip all doors at abutments and bottom flange entrances with a keyed lock and hasp. Require that all locks on an individual bridge be keyed alike.
4. Provide 2' wide minimum concrete or wood ramps at diaphragms to facilitate inspection and equipment movement. Provide ramps with a 1V:4H maximum grade (not including grade of girder) and that are continuous through the access opening. Concrete ramps shall be noncomposite and may be constructed as a secondary pour. Composite internal bottom flange build-ups used for haunched girders may serve as ramps. Design wood ramps with plywood decking. Specify marine grade plywood meeting the requirements of BS 1088 for the decking and all other wood to meet the treatment requirements of Specification 955-2.2 for pedestrian bridges.
5. See ***SDG*** 4.6.1.C.1, 5 and 6 for additional requirements.

D. See ***SDG*** 4.6.1.D for requirements for other exterior openings.

4.8.3 Initial Prestressing

A. Design U-girder segments to be initially prestressed in the casting yard by pretensioning or post-tensioning. Design the initial prestressing such that, as a minimum, the following conditions are satisfied:

1. The initial prestressing shall meet the minimum steel provisions of ***LRFD*** [5.7.3.3.2].
2. The initial prestressing shall be capable of resisting all loads applied prior to field-applied post-tensioning, including a superimposed dead load equal to 30% of the uniform weight of the girder segment, without exceeding the stress limitations for pretensioned concrete construction.
3. The initial prestressing force shall be of such magnitude that the initial deflection at release, including the effect of the dead load of the girder, shall be zero or in the positive direction. In computing the initial deflection, the value of the modulus of elasticity shall be in accordance with ***SDG*** 1.4.1 for the minimum required strength of concrete at release of the prestressing force. Reduce the prestressing force in the strands to account for losses due to elastic shortening and steel relaxation.

4. If initial prestressing is accomplished using pretensioning, the limitation on the percentage of debonded strands of the pretensioned strand group at the ends of girder segments may be increased to 37.5% provided post-tensioning is applied to the girders prior to casting the deck concrete and provided that the total number of debonded strands is equal to or less than 25% of the total area of pretensioned and post-tensioned strands at the time of placement of the deck concrete.

4.8.4 Post-Tensioning

A. Use internal post-tensioning within webs and flanges only.

B. Provisions for future post-tensioning are not required.

C. Provide integrated drawings in accordance with ***SDG*** 4.5 for anchorage zones of post-tensioning ducts and girder segments in which ducts deviate both vertically and horizontally (not including the horizontal curvature of a curved girder segment itself).

4.8.5 Transverse Concrete Deck Analysis

For spliced U-girder bridges, perform a transverse deck analysis at the Service I and Strength I load combinations using the truck and tandem portion of the HL-93 live load (do not include the lane load). For deck design, do not include the wind effects for the Service I load combination. All analyses will be performed assuming no benefit from the stiffening effects of any traffic or pedestrian railing and with a maximum multiple presence factor not greater than 1.0. For the Service I load combination in transversely prestressed concrete decks, limit the outer fiber stress due to transverse bending to $3\sqrt{f'c}$ for aggressive environments and $6\sqrt{f'c}$ for all other environments. For the Service I load combination in reinforced concrete decks, see ***LRFD*** [5.7.3.4].

8. Delete ***Structures Design Guidelines***, Section 6.8 and associated Commentary and insert the following:

6.8 ERECTION SCHEME AND BEAM/GIRDER STABILITY

A. For all bridges, investigate the stability of beams or girders subjected to wind loads during construction. For the evaluation of stability during construction use wind loads, limit states and temporary construction loads included in ***SDG*** 2.4 and ***LRFD***.

B. For simple span, non-spliced, pretensioned beams, see ***SDG*** 4.3.4 for plan requirements.

C. For all steel girder, segmental beam or box girder bridges, and CIP box girder bridges on falsework, include in the plans a workable erection scheme that addresses all major phases of erection. Investigate superstructure stability at all major phases of construction consistent with the erection scheme shown in the plans. Show required temporary support locations and associated loads assumed in design. Coordinate temporary support locations with the Traffic Control Plans. See ***PPM***, Volume 1, Article 10.4. Show maximum allowable vertical displacements of the temporary supports in the plans as required for fit up, alignment, and stability, or where excessive settlements would affect stresses of the permanent structure.

D. For curved spliced U-girders, if temporary supports are located only at the ends of segments, show the required service torsional and vertical reactions as well as maximum allowable vertical displacements at all temporary supports.

E. For information not included in the ***SDG*** or ***LRFD***, refer to the ***AASHTO Guide Design Specifications for Bridge Temporary Works*** and the ***AASHTO Construction Handbook for Bridge Temporary Works***.

Commentary: The contractor is responsible for evaluating the stability of individual components during erection. Shallow foundations for temporary supports may not be appropriate under certain circumstances due the impacts of settlement on the permanent structure.

9. Delete ***Structures Detailing Manual***, Section 22.3.H and insert the following:

H. Longitudinal or vertical conveyance piping is not permitted inside post-tensioned U-Girders nor inside enclosed spaces, e.g. box beams, standard Florida-U beams, pretensioned U-Girders, hollow piers, etc., that cannot be directly inspected. Where possible, avoid placing longitudinal conveyance piping inside box-type superstructures regardless of inspectability, or in highly visible areas such as under deck cantilevers. When longitudinal conveyance piping must be placed inside box-type superstructures, locate deck drain inlets as close to pier locations as possible to minimize the length of piping inside the superstructure.

COMMENTARY

Per ***LRFD*** 5.14.1.3-1, spliced U-girders are not to be considered as segmental construction for the purposes of design. However, due to the inherent complexity involved in designing spliced U-girder bridges, per the Implementation Plan, designers shall be qualified for work type 4.2.3 Major Bridge Design-Segmental.

Construction of spliced U-girder bridges includes pre-casting either straight or curved sections, supporting the sections using temporary supports as required and splicing the sections together using post-tensioning. For curved structures, a lid slab is cast after the girder segments are erected and before the continuity post-tensioning is applied to increase the torsional resistance of the section. After the section is closed and stressed, forms are placed between the boxes and a full depth deck is cast.

Span lengths for these structures can be extended by providing haunched sections at the piers.

Advantages to this type of construction compared to conventional construction include:

- Lower fabrication times
- Faster construction
- Ability to span longer distances
- Increased aesthetics by providing a unified appearance

Characteristics of this type of construction include:

- Requires extensive temporary shoring
- Typically entails heavy girder sections and larger cranes to place
- Requires more field and erection engineering than typical beam construction
- Stability must be designed for and maintained until superstructure is self supporting.
- Monitoring of settlement of temporary foundations during erection through post-tensioning is required.

Extensive coordination with SDO will be required for initial projects.

BACKGROUND

With the implementation of the Department's Innovative Project Solutions Initiative, the Structures Design Office has taken the initiative to increase the inventory of constructible, standard, reliable and innovative bridge solutions. By increasing the inventory of available standard bridge types and cross-sections, the Department expects to see more cost-effective designs that will not sacrifice the aesthetics or infrastructure quality that is realized by the traveling public.

Spliced girder bridges are typically used for continuous structures in order to facilitate longer spans. In the past, spliced girders have been limited to straight concrete I-girder sections. New spliced U-girder technologies now allow for straight and curved U-shaped bridge options. Several have already been successfully constructed in Colorado.

The U-girder section will eventually be a standardized shape and will offer a competitive solution to steel box girders and concrete segmental bridges where previously no alternative was available.

IMPLEMENTATION

This bridge type is available for consideration on all projects immediately and its implementation and use is at the discretion of the District.

These requirements are effective immediately on all design-bid-build projects in Phase I design development (less than 30% complete).

These requirements are effective immediately on all design build projects for which the final RFP has not been released. Design build projects that have had the final RFP released are exempt from these requirements unless otherwise directed by the District.

All consultants designing spliced U-girders or performing work as Specialty Engineers for spliced U-girders shall be qualified in accordance with Rule 14-75 Florida Administrative Code, Work Group 4.2.3: Major Bridge Design - Segmental. Ultimately, it is the Department's intent to update Rule 14-75, Florida Administrative Code, in order to incorporate the qualification requirements for firms or engineers designing Spliced U-Girders within the work type description for Standard Work Type 4.2.3. Until such time, District Procurement shall advertise work type 4.2.3 Major Bridge Design-Segmental whenever the structures project requires spliced U-girders, as assessed by the

District Structures Design Engineer. Please contact Central Office Structures if there are any questions.

Until the Specifications are revised to fully address all aspects of construction using spliced U-girders, the Engineer of Record for the spliced U-girder project shall develop the necessary Technical Special Provisions which address all Specialty Engineering requirements during construction including but not limited to the following:

1. Erection Manual: Before commencing erection operations, submit proposals for all U-girder erection operations to the Engineer for approval. This submittal must be in the form of an "Erection Manual" and must include but not necessarily be limited to:

   A. A step-by-step sequence for the erection of each U-girder segment including all intermediate procedures relating to erection equipment, temporary and permanent post-tensioning and the construction of closures.
   B. Positioning, use and sequencing of falsework, jacking and/or releasing of falsework, temporary towers, supports, tie-downs, counterweights, closure devices and the like.
   C. Positioning, use and sequencing of erection equipment such as cranes, beam and winch devices, gantries, trusses and the like, both on and off the structure, including the movement, introduction and/or removal of any supports onto or connections with the structure. Include drawings and calculations for the structural effects of erection equipment on the structure.
   D. Detailed scheduling of all temporary and permanent post-tensioning operations and sequences in accordance with the U-girder section erection and closure operations and other required scheduling.
   E. Stressing forces and elongations for post-tensioning.
   F. Sequencing of grouting operations.
   G. A method for the field survey control for establishing and checking the erected geometry (elevations and alignments), settlement monitoring of temporary towers, jacking of U-girder sections prior to casting of closure pours, etc.

2. Geometry Control: Establish the key stages for checking of the erection sequence shown in the Erection Manual and obtainment of the Engineer's review and approval. Key stages would include, for example, setting each U-girder segment. Prepare a table of elevations and alignments required at each key stage of erection in accordance with the Plans, as cast geometry, camber and erection elevations for establishing erection controls and submit to the Engineer for approval. Carefully check elevations and alignments at each stage of erection. Provide temporary tower settlement monitoring and jacking requirements.

3. Shop drawing requirements associated with spliced U-girders.

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