Washington State Department of Transportation
Bridge and Structures Office

Design Memorandum

TO: All Design Section Staff
FROM: Bijan Khaleghi
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SUBJECT: New WSDOT wide flange Deck Bulb Tee girders with UHPC Connections

This design memorandum introduces the newly developed wide flange deck girder type with Ultra High Performance Concrete (UHPC) flange closures. These new girders have the same cross sectional dimensions as standard WSDOT wide flange girders, except that the flange width has been increased to vary between 5 feet and 8 feet. The top flange has also been thickened to support traffic and superimposed dead loads without the need for a cast-in-place reinforced concrete deck. These new girder types will allow more efficient bridge superstructures to be constructed without the need for deck formwork, facilitating accelerated bridge construction (ABC) with particular applicability to the WSDOT Fish Passage culvert replacement program.

The use of precast prestressed deck girders with cast-in-place (CIP) UHPC connections has the potential to produce higher quality, more durable bridge decks. UHPC can significantly shorten the development length of embedded discrete steel reinforcement and can exhibit exceptional bond with previously cast concrete. The transverse connections between adjacent girders shall be based on use of CIP UHPC with lapping bars at the connection. The minimum closure width for CIP-UHPC shall be 9 inches. This new deck system requires 1 ½” thick concrete overlay at the time of initial construction. The first 1” could be used for structural design and the remaining ½” is considered as wearing surface.

Table 1 shows the span capability of wide flange deck girders with UHPC connections for both normal weight and light weight concretes. Light weight concrete may be used on a case-by-case basis upon approval by the WSDOT State Bridge Design Engineer, except for expanded slate produced by the rotary kiln method conforming to ASTM C 330.

Table 1 Span capability of WF--DG girders with UHPC connections

		Normal Weight Concrete	Lightweight Concrete
Girder Type	**Girder Spacing (ft)**	**CL Bearing to CL Bearing (ft)**	**CL Bearing to CL Bearing (ft)**
WF42DG	5	135	140
	6	130	135
	7	120	125

	8	110	120
WF45DG	5	150	160
	6	145	155
	7	135	145
	8	125	135
WF53DG	5	170	180
	6	165	170
	7	155	165
	8	145	155
WF61DG	5	185	195
	6	180	190
	7	175	180
	8	160	175
WF69DG	5	200	210
	6	185	205
	7	175	195
	8	165	190
WF77DG	5	190	225
	6	180	220
	7	170	210
	8	160	200
WF86DG	5	180	230
	6	170	220
	7	160	205
	8	155	195
WF98DG	5	170	220
	6	160	205
	7	155	195
	8	145	185
WF103DG	5	165	215
	6	160	200
	7	150	190
	8	145	180

- NOTE: Shaded cells indicate span lengths that are limited by a shipping weight of 252 kip.

The following limitations are recommended for WF-DG Girders with UHPC Connections:

- WF42DG, WF45DG, WF53DG, WF61DG, WF69DG, WF77DG, WF86DG, WF98DG, and WF103DG are standard girders.

    - WF77DG, WF86DG, WF98DG, WF103DG should only be used when non-roadway delivery options are available. These girders exceed the standard 252 kip shipping weight limit at shorter span lengths than shorter height girders
- Maximum top flange width is 8 feet
- Erect WF42DG, WF45DG, and WF53DG with the web plumb or perpendicular to the roadway surface. Erect all other girders with the web plumb.
- Use transverse top flange thickening to accommodate crown slopes for girders erected with plumb webs
    - Top flange overhangs will be equal length on either side of the web. The transverse top flange thickening will cause the center of mass to offset from the centerline of the web. Consider this for lifting and shipping stability analysis.
- Precise fit-up between the top flanges of adjacent girders is necessary for a quality UHPC connection joint. When the ends of girders are skewed, top flange edges are vertically offset relative to one another due to camber. This is commonly known as the “saw tooth” effect. The “saw tooth” effect can be accommodated by:
    - negating the effects of camber with longitudinal top flange thickening or precamber
    - adjusting the bearing elevations so that adjacent top flanges align. Adjustments typically consist of raising one end of the girder and lowering the other to match the profile of the adjacent girder. This approach is only viable if the roadway profile is made to match the camber.
- Cross slope should not exceed 0.04 ft/ft.
    - If crown slope exceeds 0.04 ft/ft biaxial bending stresses shall be considered for both web perpendicular to roadway surface and plumb web with transversely thickened top flange.
- Maximum angular difference between two adjacent lines of support is 10°.
- Maximum skew angle is 45°.
- Horizontal curves
    - Avoid horizontal curves, especially those with small radii.
    - Do not use in superelevation transitions
    - When used in a full superelevation, alert roadway designers that cross slope will be normal to the centerline of the bridge (not radial). The cross slope will cause a “flat spot” in the curve, especially for longer spans and may yield an undesirable riding surface.
- Vertical curves
    - Work with roadway designers to match crown vertical curves to girder camber and pier elevation adjustments.
    - Use overlay build-up, longitudinal top flange thickening, or pre-camber to match profile grade as needed.
- All girders in the cross section should have the same top flange width.

  - When using a UHPC closure joint, small increases in the joint width is preferred to accommodate a specific overall bridge width to using different top flange widths.
  - Use different top flange widths to accommodate a specific overall bridge width, if needed. Ensure that there is not a large disparity in prestressing requirements, camber, and girder stiffness and that standard girder leveling techniques can eliminate differential camber.
  - Top flange width of exterior girders shall be sufficient to accommodate the wing wall and girder stop.
- Minimum width of UHPC Closure Joints is 9”. Avoid using joints that are wider than necessary. UHPC is an extremely expensive material.
- Do not use this structure type for continuous bridges for the following reasons
  - Adequate continuity connection details have not been developed
  - Excessive amounts of reinforcement may be required in the top flange to establish continuity. This reinforcement will cause differential shrinkage between top and bottom flanges and will cause additional camber.
- Do not use this structure type where the bridge vertical clearance is less than 16’-6” and if there is a chance of high load impact. UHPC joints are extremely difficult to disassemble making girder replacement very challenging.

The shipping weight limits are for a single girder segment and do not include the weight of the hauler. These limits are conservative and are set low to ensure that all girders can be trucked to all jobsites. Girders with shipping weight exceeding 270 kips could be shipped to some specific projects.

The Design Parameters for span capability charts are:

- PGSuper Version 2.9.0
- Girder f'_{ci} = 7.5 ksi, f'_c = 10.0 ksi
- UHPC Closure = f'_c=14 ksi
- Includes 1 ½” overlay with density of 160 pcf
- Shipping weight < 252 kip
- No vertical or horizontal curve
- Standard WSDOT 42” Single Slope barrier
- 2% roadway crown slope with ±20% impact for shipping stress check
- 6% roadway superelevation for shipping stress and stability checks
- Standard WSDOT Abutment End Type A
- Includes 3" future HMA overlay with density of 140 pcf

At this time, design transverse top flange reinforcement on a case-by-case basis. The reinforcement depends on the top width of the girder and the strength of the girder concrete.

Skews complicate the detailing of this reinforcement.

Standard girder sheets and UHPC connection details are being developed. They will be added to the BDM, by memorandum, at a later date.

Background:

Precast concrete deck girders are a preferred solution for projects where Accelerated Bridge Construction (ABC) is considered. The use of precast concrete superstructures results in speed of construction, while minimizing traffic disruption and environmental impact. Advanced cementitious composite materials, whose mechanical and durability properties far exceed those of conventional concretes, present an opportunity to significantly enhance the performance of field cast connections, thus facilitating the wider use of modular bridge deck systems.

The Washington State Department of Transportation (WSDOT) has developed new wide flange deck girders to accommodate accelerated bridge construction. The new wide flange deck girders could be fabricated using either normal weight or light weight aggregates concretes. Ultra-high performance concrete (UHPC) in lieu of the welded ties and grouted keys is considered for connection between girders to improve the performance of the connection between girders. This memorandum summarizes the development of new wide flange deck girders for accelerated bridge construction. A current WSDOT research project on the use of UHPC for precast concrete deck girders is referenced.

WSDOT has recently completed research projects with the Washington State University and the University of Washington studying the Connection of Wide Flange Deck Bulb using UHPC and overlapping bars within the CIP UHPC closure.
NCHRP Project 12-69 provides additional guidance for the design and construction of decked precast concrete girder bridges.
Full height CIP concrete intermediate diaphragms are required for bridges built over traffic. Intermediate diaphragms are not required for water crossings or where the possibility of overheight impact is rare. Steel or other materials could be used temporary intermediate diaphragms during construction.

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