DECK BULB TEE GIRDER BRIDGES

David Liu, PhD, SE, PE, Parametrix, Portland, OR
Steve Haines, PE, Parametrix, Denver, CO

ABSTRACT

Precast Deck Bulb Tee girder refers to a bulb tee girder with the top flange modified to precast the deck slab with the bulb tee girder. Girders are placed with the top flanges adjacent to form the deck of the bridge. To make the deck continuous and allow for live load distribution the top flanges are mechanically connected and grouted in the field. The advantage with the use of Deck Bulb Tee girder bridges is to speed up superstructure design and construction because in most cases the concrete deck is not required and only a 2" minimum wearing surface is applied to the top of girders. The Deck Bulb Tee girder is widely used in Northwest region, however this type of girder is rarely used in other parts of the country. In cold regions, where the construction season is short, the use of Deck Bulb Tee girders is a good option to consider due to the reduced amount of on-site construction required. This is also true for fast track projects when the construction schedule is a primary concern.

Keywords: Deck Bulb Tee girder, Bridges, Accelerated Construction.

INTRODUCTION

Precast Deck Bulb Tee girder refers to a bulb tee girder with the top flange modified to precast the deck slab with the bulb tee girder. Girders are placed with the top flanges adjacent to form the deck of the bridge. To make the deck continuous and allow for live load distribution the top flanges are mechanically connected and grouted in the field. The advantage with the use of Deck Bulb Tee girder bridges is to speed up superstructure design and construction because in most cases the concrete deck is not required and only a 2" minimum wearing surface is applied to the top of girders. The Deck Bulb Tee girder is widely used in Northwest region, however this type of girder is rarely used in other parts of the country. In cold regions, where the construction season is short, the use of Deck Bulb Tee girders is a good option to consider due to the reduced amount of on-site construction required. This is also true for fast track projects when the construction schedule is a primary concern.

In this paper, the application of Deck Bulb Tee girder bridges in Oregon, Washington and Idaho is reviewed. Some concerns about design, construction and performance are discussed. The cost of the Deck Bulb Tee girder is also compared with Prestressed Concrete girder, Prestressed Concrete slab and Post-Tensioned Concrete Box girder.

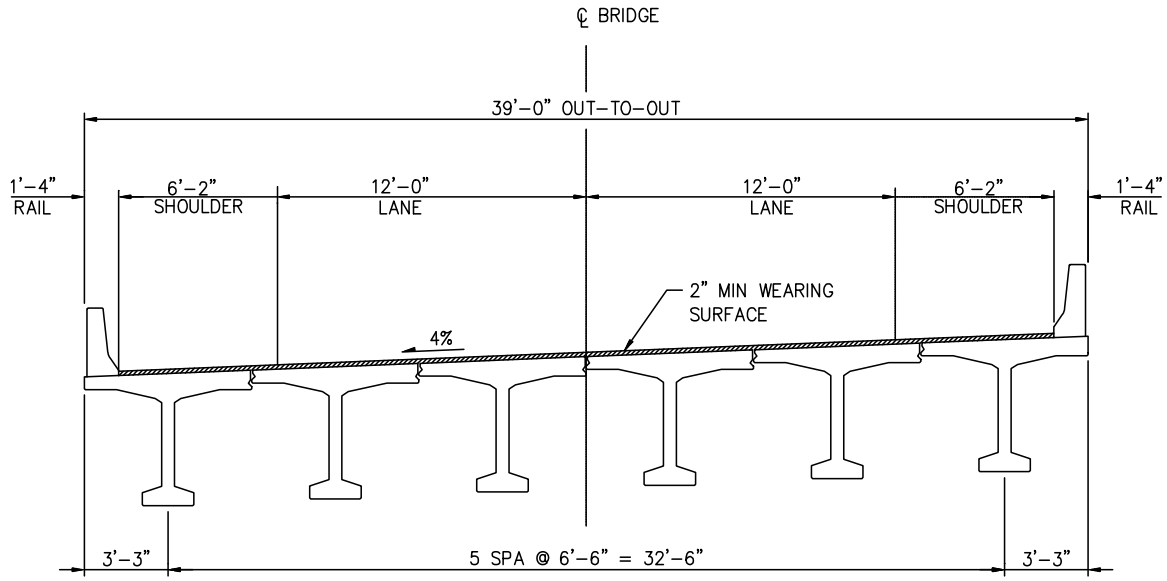


Fig. 1 Typical Section of Deck Bulb Tee Girder Bridge

OREGON PRACTICE

Oregon began using the Deck Bulb Tee girder about 32 years ago. Lostine River (Wolf) Bridge in Wallowa County was the first Deck Bulb Tee girder bridge designed in Oregon in 1975. Since then Deck Bulb Tee girder bridges have been designed and built throughout Oregon.

In Oregon, Deck Bulb Tee girder bridges are typically used for single span, low-volume traffic routes and non-interstate routes. For interstate routes and routes with 20-year projected ADTT > 1000, a minimum 7 ¼" high performance concrete cast-in-place deck is required. Because of this requirement, the Deck Bulb Tee girder is generally used only on low-volume routes. For non-interstate routes and routes with 20-year projected ADTT < 1000, a minimum 2" asphalt concrete wearing surface (ACWS) with membrane waterproofing or a minimum 7 ¼" high performance concrete cast-in-place deck is required[1].

Currently, the Oregon Department of Transportation (ODOT) bridge drawings[2] provide standard Deck Bulb Tee girder details for 3'-0", 3'-9", 4'-6" and 5'-0" deep girders. The top flange width varies from 5'-0" to 8'-6". The minimum top flange thickness is 6 inches. The end view and mid-span section are shown in Figs. 2 and 3 respectively.

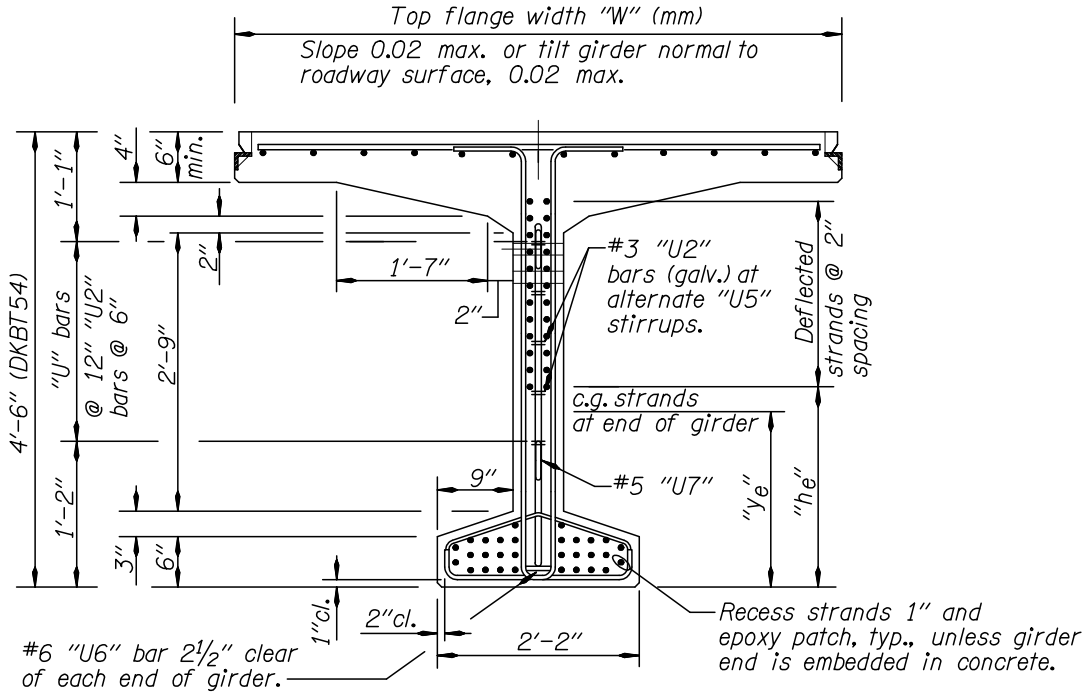


Fig. 2 Girder End View (ODOT)

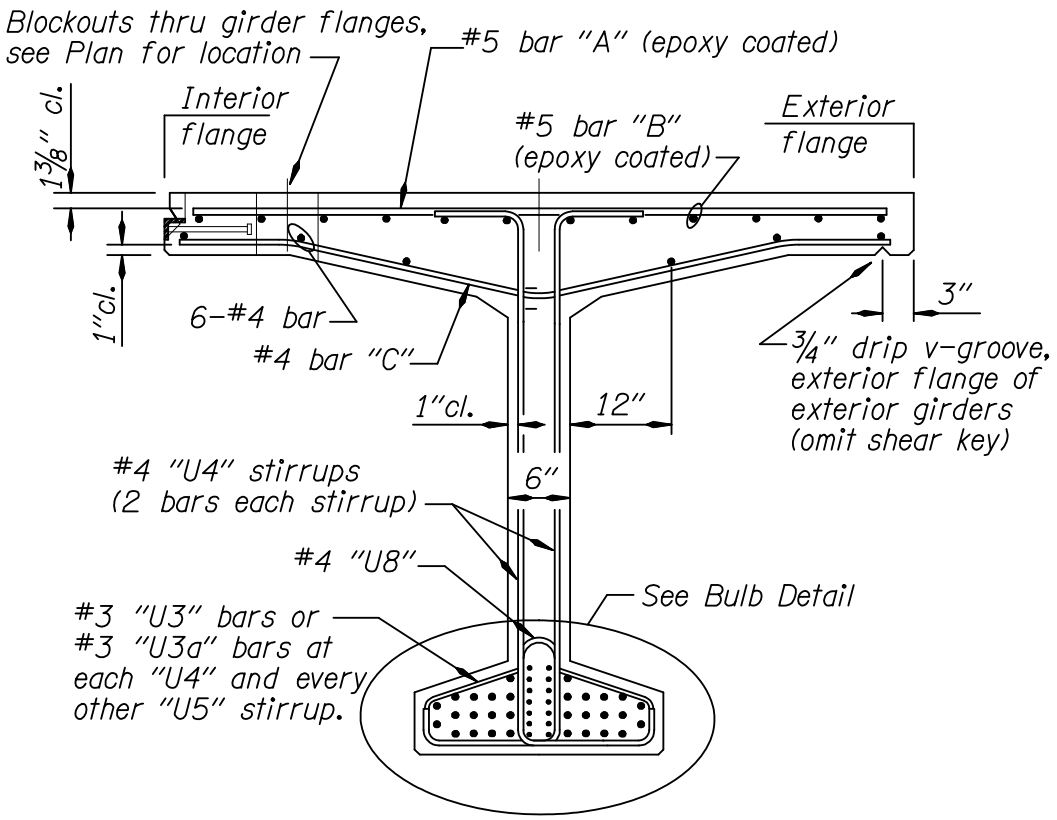


Fig. 3 Girder Mid-Span Section (ODOT)

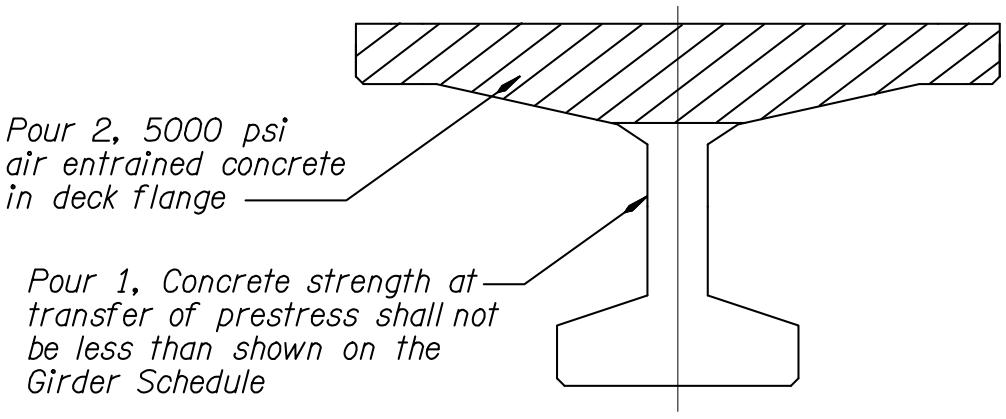


Fig. 4 Concrete Pour Sequence (ODOT)

The concrete pour sequence for a typical Deck Bulb Tee girder is shown in Fig. 4. The maximum concrete strength for the top flange is 6000 psi. This limitation is required to ensure adequate air entrainment and to ensure adequate workability of the concrete. Higher strength concretes are generally less workable and therefore are more difficult to achieve an acceptable finish suitable for a riding surface. The maximum concrete strength for the web and bottom flange portions is 9000 psi[1]. The concrete mix design shall contain entrained air from 4% to 7% for the top flange portion of the girder, entrained air is not required for web and bottom flange[3].

The typical flange shear connector details are shown in Fig. 5. The mechanical portion of the shear connector is spaced at 5'-0" and the maximum distance from the first shear connector to the end of girder is 7'-6". The flange shear connector contains a grouted shear key which is continuous along the full length of the girder.

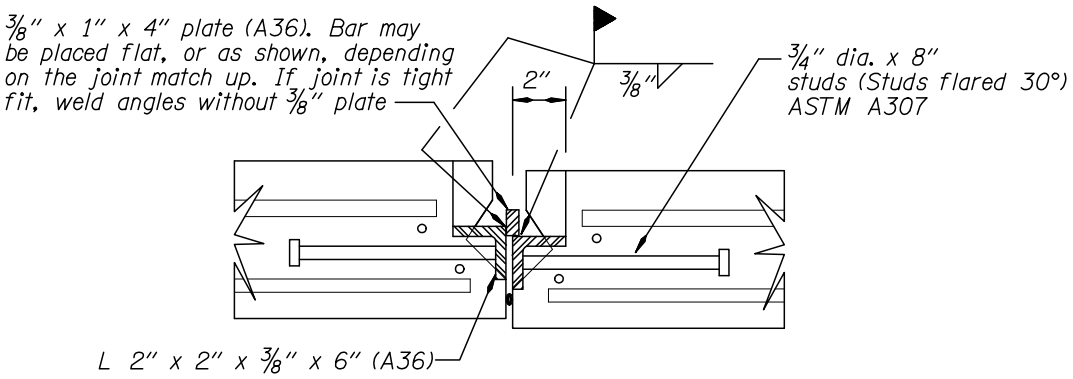


Fig. 5 Flange Shear Connector (ODOT)

IDAHO PRACTICE

Currently, Idaho Transportation Department (ITD) bridge standard drawings provide standard Deck Bulb Tee girder details for 3'-1" thru 6'-0" deep girders[4]. The maximum top flange width is 7'-0" or 8'-0" depending on the fabricators. The top flange thickness is 8 inches. The end view and mid-span section are shown in Figs. 6 and 7 respectively. For concrete mix design, entrained air shall be 5% with a 1% tolerance.

The weld tie connection detail is shown in Fig. 8. The weld tie connection is spaced at maximum of 5'-0" and the maximum space at the end of girder is 3'-6". The configuration of the weld tie connection requires the girder camber to be equalized between girders prior to installation of the weld tie connection.

ITD specifies the following construction sequence for Deck Bulb Tee girders:

1) Erect girders and install temporary bracing.

2) Equalize girder camber, install weld tie connections (minimum of 3), release equalizing equipment, move equalizing equipment to next location, and repeat this step as needed.
3) Install all remaining weld tie connections.
4) After all weld tie connections have been installed, the following activities may proceed at the contractor's discretion: grout shear key, cast intermediate diaphragms, and cast end diaphragms.
5) Remove temporary bracing.

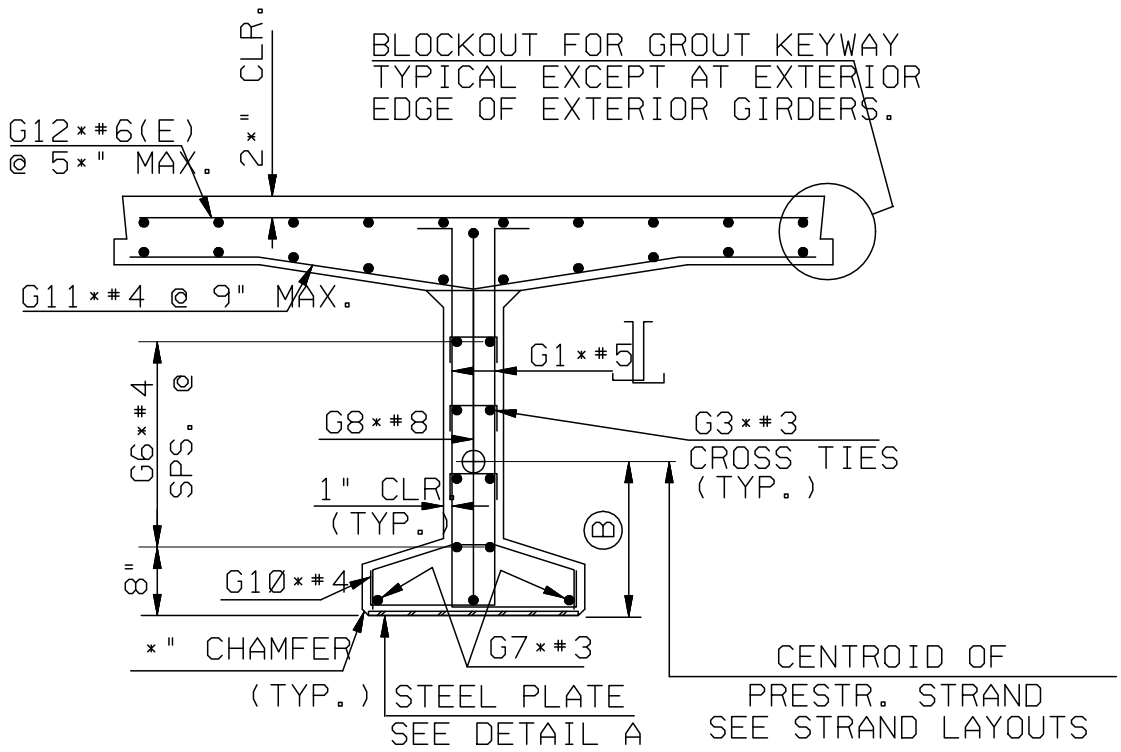


Fig. 6 Girder End View (ITD)

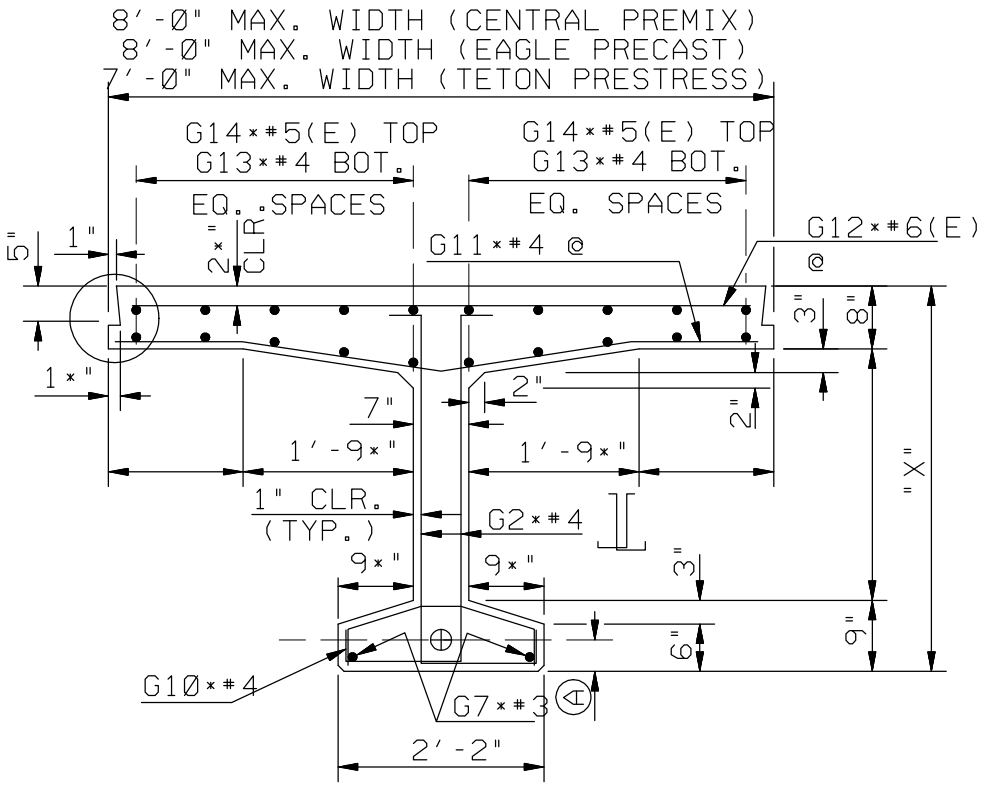


Fig. 7 Girder Mid-Span Section (ITD)

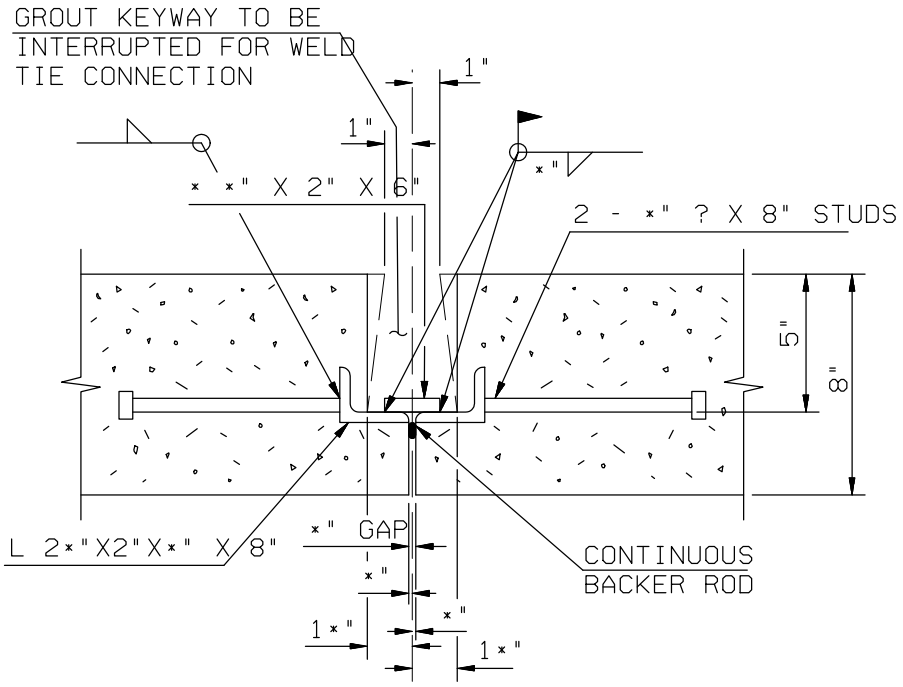


Fig. 8 Weld Tie Connection (ITD)

WASHINGTON PRACTICE

Washington State has utilized Deck Bulb Tee girders since 1969 when they were first developed by Arthur Anderson for the use by local agencies and the U.S. Forest Service[5]. The current design approach allows the use of Deck Bulb Tee girders only for low ADT roads (<10000). This limit is based mainly on the durability of the longitudinal joint between the adjacent girders.

The Washington Bridge Design Manual contains 4 Deck Bulb Tee girder cross sections ranging in depth from 35" to 65" deep, typical girder dimensions are shown in Fig. 9. Standard flange widths are available in 4'-0", 5'-0" and 6'-0" dimensions[6].

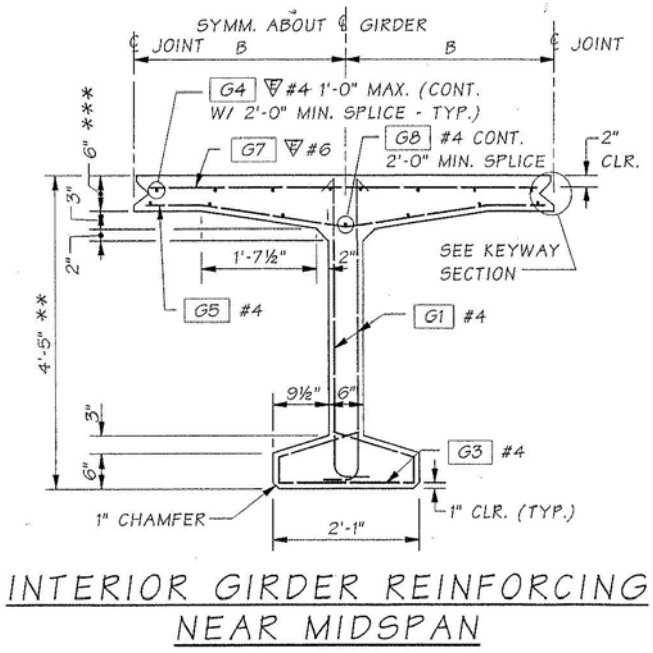


Fig. 9 Typical DBT Dimensions (WSDOT)

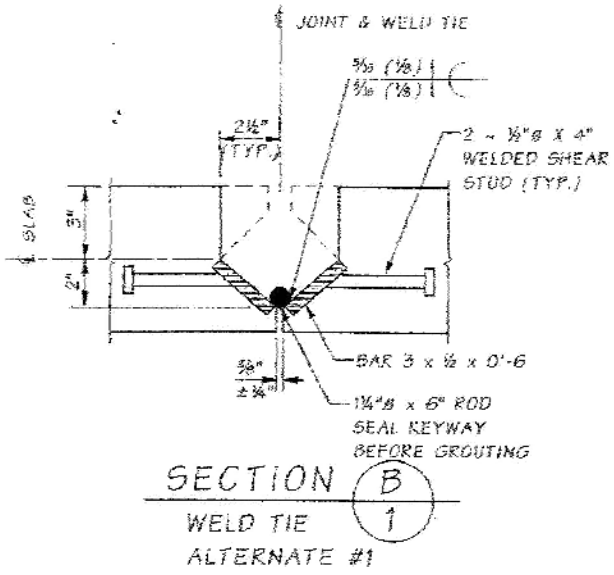
Individual girders are designed as simply supported beams between supports for single span and multiple span bridges. Compensation for camber variances due to the girder prestressing is handled by varying the thickness of the top flange. Practical girder span capabilities range from 60 ft to 145 ft based on standard concrete strengths.

Table 1 Span Capacity of Deck Bulb Tee Girders

	F_{ci} = 4.0 ksi f_c' = 5.0 ksi		F_{ci} = 5.0 ksi f_c' = 6.0 ksi	
Girder Type	Flange Width (ft)	Max Span (ft)	Flange Width (ft)	Max Span (ft)
W35DG	4	85	4	95
	5	70	5	80
	6	60	6	70
W41DG	4	95	4	105
	5	80	5	95
	6	70	6	80
W53DG	4	115	4	125
	5	105	5	120
	6	90	6	105
W65DG	4	135	4	145
	5	125	5	140
	6	110	6	125

Washington State utilizes a continuous grouted joint in conjunction with mechanical connectors at 4 feet to 8 feet intervals. The combination transfers the tensile loads between the girder top flanges. The grouted joint consists of a female-to-female shear key configuration. The grouted joint is grouted with non-shrink grout. Washington State has developed 3 alternate top flange mechanical connectors between girders, see Figure 10.

The Deck Bulb Tee girders receive a 2" asphalt overlay with waterproofing membrane. This system provides a flexibility that helps prevent reflective cracking that is common with concrete overlays.



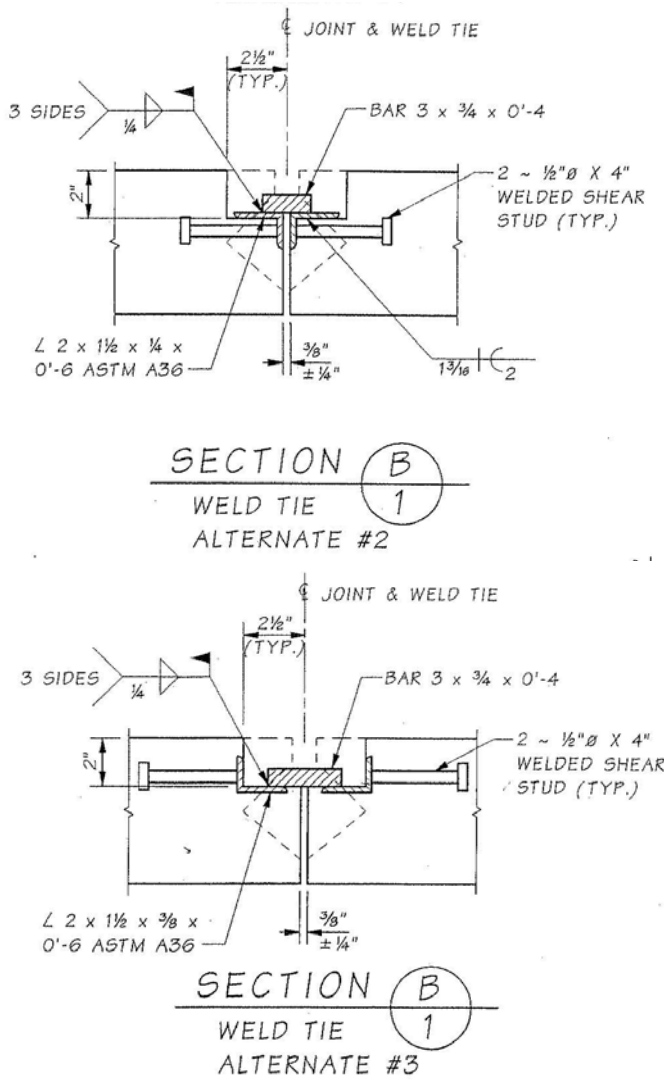


Fig. 10 Alternate Mechanical Connectors (WSDOT)

The final deck gets overlaid with 2” of asphalt and a waterproofing membrane.

DESIGN AND CONSTRUCTION ISSUES

During the bridge type study phase of a project, the following factors should be taken into consideration while evaluating the potential use of Deck Bulb Tee girders:

1) Excessive asphalt concrete wearing surface (ACWS) build-up at abutments and piers would occur for sagged vertical curves. This is also true if cast-in-place concrete deck is used.

2) Due to much wider and thicker top flange, Deck Bulb Tee girders are much heavier than Bulb Tee girders. Shipping requirements such as girder weights, girder length and girder stability should be consulted with local fabricators.
3) If the bridge is constructed in stages, temporary barrier attachment to the top flange during staged construction should be investigated. In order to meet FHWA requirements for crash tested temporary rail attachments, it is likely required to place barrier anchors thru the top flange of the Deck Bulb Tee to prevent the temporary barrier from sliding and overturning. Neither drilling holes into top flange in the field or providing blockouts for the holes in the shop are good options due to the required labor and conflicts with reinforcing. According to Oregon Bridge Design and Drafting Manual[1], Restraints will not be required if the barrier can be displaced 3 feet or more away from the traffic side without infringing on a traffic lane, a work area, or beyond the edge of the deck.

Design of the Deck Bulb Tee girder is similar to the Bulb Tee girder design except when AASHTO LRFD is used for skew bridges[7]. The correction factor for load distribution factors for support shear of the obtuse corner is not defined for Deck Bulb Tee girder bridges. Therefore, either refined methods of analysis or engineering judgment shall be used to magnify support shear of the obtuse corner.

In Oregon, lower concrete strengths are used for the top flange portion of the girders and higher concrete strengths are used for the web and bottom flange portions. Typical prestressed concrete girder design programs may not have the capability to handle the different concrete strengths. Therefore, the transformed section shall be use to evaluate stresses and camber at the transfer of prestress, and stresses and deflections under full service loading. The stresses reported in the top of the girder shall be multiplied by the appropriate modular ratio. For strength computations, the lower concrete strength is used for flexural analysis and the higher concrete strength for shear analysis. The gross section properties should be used for strength computations.

COST ANALYSIS AND DESIGN EXAMPLES

The average unit costs from the Washington Department of Transportation Structural Estimating Aids for Deck Bulb Tee Girder, Prestessed Concrete Girder, Post-Tensioned Concrete Box Girder, and Prestressed Concrete Slab bridges are shown in Table 2.

Table 2. Construction Costs (WSDOT)

Girder Type	Span Range	Unit	Cost
Deck Bulb Tee Girder	40 – 115 FT.	SF	$125
Prestressed Concrete Girder *	50 – 175 FT.	SF	$140
Post-Tensioned Concrete Box Girder *	50 – 200 FT.	SF	$155
Prestressed Concrete Slab	13 – 69 FT.	SF	$110

* - Dry crossing with piling.

From the table it can be seen that the Deck Bulb Tee Girder provides the most economical option for span lengths ranging from 70 to 115 feet.

SCAPPOOSE-VERNONIA ROAD BRIDGE, OREGON

Scappoose-Vernonia Road over East Fork of Nehalem River Bridge is located in Columbia County, Oregon. This replacement bridge is a 108 feet long, single span, Deck Bulb Tee girder bridge. The bridge carries two-lanes of traffic supported by six Deck Bulb Tee girders as shown in Fig. 1. The Deck Bulb Tee girders are 5'-0" deep with a top flange width of 6'-6". The top flange of the Deck Bulb Tee girder is sloped at 4% to provide the required transverse superelevation. The concrete strengths utilized were 6000 psi concrete for the web and bottom flange portion of the girders and 6000 psi air entrained concrete for top flange. Each girder has 20 straight strands and 20 deflected strands. The prestressing strands are 0.5-in diameter, grade 270 strands with low relaxation. Each girder had a shipping weight of approximately 135 kips.

The asphalt concrete wearing surface varied due to the vertical profile of the roadway and resulted in a maximum build-up at the abutments of approximately 4 7/8 inches. Integral abutments are utilized to eliminate the girder bearings and the bridge expansion joints. The bid construction cost, excluding mobilization, was $107/SF.

UPTON ROAD OVER BEAR CREEK BRIDGE, OREGON

Upton Road over Bear Creek Bridge is located in Jackson County, Oregon. This is a 285 feet long (85'-100'-100' per span), three-span, Deck Bulb Tee girder bridge. The bridge carries three-lanes of traffic with a sidewalk on each side. The structure is on a horizontal alignment that transitions from a tangent to a curved alignment. The radius of the horizontal curved portion along the centerline of the roadway is 4500 feet. The framing layout on the curved portion of the alignment places the centerline of the girders parallel to a chord line. The typical deck section is shown in Fig. 11. The maximum concrete strength of 8000 psi was utilized for the web and bottom flange portion of the girders and 6000 psi air entrained concrete for top flange. The maximum girder shipping weight is approximately 132 kips.

Maximum Asphalt concrete wearing surface build-up at the abutments and piers is approximately 7 1/2 inches due to the vertical profile of the roadway. Integral abutments are utilized to eliminate the girder bearings and the bridge expansion joints. The structure is

built in two stages to allow traffic to be maintained during the construction. The bid construction cost, excluding mobilization, was $137/SF.

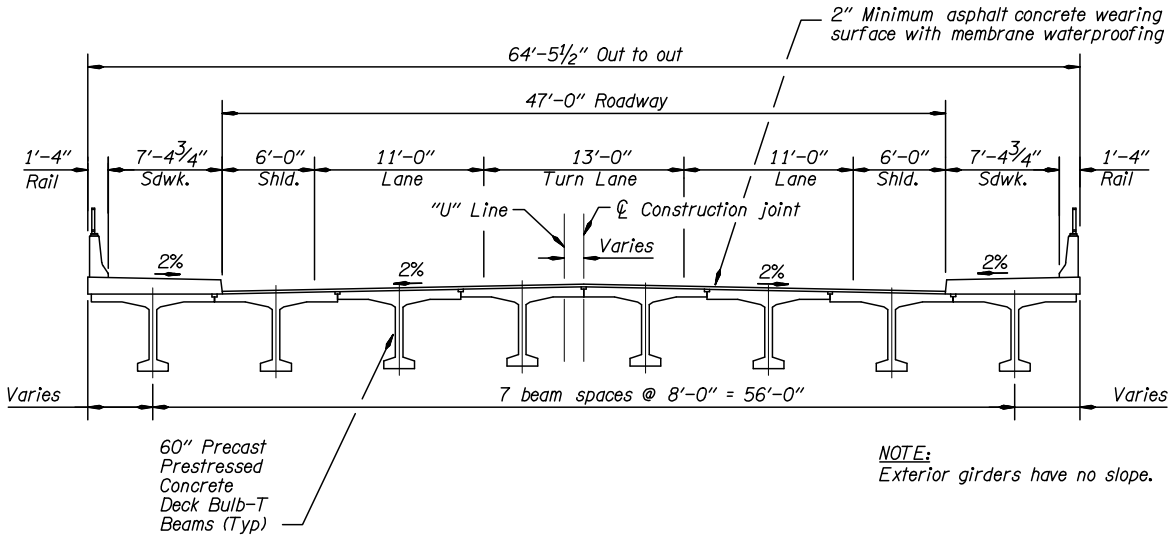


Fig. 11 Upton over Bear Creek Typical Section

CONCLUSIONS

The main advantage to using the Deck Bulb Tee girder bridges is to speed up the superstructure design and construction. Typical practice is to utilize the Deck Bulb Tee girder bridge when the traffic volume is low and a cast-in-place deck is not required. This limitation is mainly due to the capacity of the shear connection between the flanges and the capacity to resist the required live loads.

The Deck Bulb Tee girder is preferred to be used in single span, straight bridges, with span lengths from 70 to 115 feet. When used in continuous spans, special details at the pier diaphragms must be considered during the bridge type selection process. In most cases, the Deck Bulb Tee girders have a lower construction cost than Prestressed Concrete girders and Post-Tensioned Concrete Box girders.

ACKNOWLEDGEMENT

The authors would like to acknowledge Craig Shike, Concrete Bridge Standards Engineer, Oregon Department of Transportation, for providing valuable input on the history and practices of the Deck Bulb Tee girder within the State of Oregon.

REFERENCES

1. Oregon Department of Transportation, "Bridge Design and Drafting Manual 2004," *Oregon Department of Transportation*, Salem, Oregon, updated Apr. 2007, pp. 1-148, 1-149 and 1-221.

   Available online at: http://www.oregon.gov/ODOT/HWY/BRIDGE/docs/BDDM/apr-2007_finals/pdf/section_1-2004_apr07.pdf (July 29, 2007).

2. Oregon Department of Transportation, "Bridge Standard Details," *Oregon Department of Transportation*, Salem, Oregon, 2006, Detail No. DET3370 and DET3380.

   Available online at: http://www.oregon.gov/ODOT/HWY/ENGSERVICES/details_bridge.shtml#Prestressed_Beams (July 29, 2007).

3. Oregon Department of Transportation, "Oregon Standard Specification for Construction," *Oregon Department of Transportation*, Salem, Oregon, 2002, pp. 385.

   Available online at: http://www.oregon.gov/ODOT/HWY/SPECS/2002_std_specs.shtml (July 29, 2007).

4. Idaho Transportation Department, "Bridge Design LRFD Manual," *Idaho Transportation Department*, Boise, Idaho, Sept. 2006, Article B5.0.

   Available online at: http://itd.idaho.gov/bridge/manual/manualcover.htm (July 29, 2007).

5. Shah, B., Sennah, K., Kianoush, M., Tu, S., and Lam, C., "Flange-to-Flange Moment Connections for Precast Concrete Deck Bulb-Tee Bridge Girders," *PCI Journal*, V. 51, No. 6, November-December 2006, pp. 86-107.

6. Washington State Department of Transportation, "Bridge Design Manual LRFD," *Washington State Department of Transportation*, Olympia, Washington, Feb. 2007, Chapter 5.

   Available online at: http://www.wsdot.wa.gov/fasc/EngineeringPublications/BDMManual/chapter05.pdf (July 29, 2007).

7. AASHTO, "AASHTO LRFD Bridge Design Specifications," *American Association of State Highway and Transportation Officials*, Washington, DC, 4th Edition, 2007, pp. 4-44.