OREGON'S FIRST CONTINUOUS DECK BULB TEE GIRDER BRIDGE

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ABSTRACT

A precast prestressed concrete Deck Bulb Tee girder is similar to a standard bulb tee girder with the exception that the top flange is intended to act as the structural deck and is therefore designed to support traffic loads. The top flanges can be upwards of 8 feet in width and are connected in the field using welded tie connections with a grouted shear key. Similar to adjacent box beams, Deck Bulb Tee girders are mostly used for single span bridges but are occasionally used for multi-span bridges. A primary advantage of using Deck Bulb Tee girders is to speed up construction by applying a wearing surface to the top of the girders in lieu of a concrete deck. However, providing continuity for a multi-span, Deck Bulb Tee girder bridge without a concrete slab poses many challenges. In this paper, the design of Oregon's First Continuous Deck Bulb Tee Girder Bridge is presented. Unlike conventional precast concrete I-girder bridges, this three-span structure supported by 17-ft tall integral abutments and integral piers provides continuity at the piers using only the top flange of the Deck Bulb Tee girders and diaphragms.

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

INTRODUCTION

A precast prestressed concrete Deck Bulb Tee girder is similar to a standard bulb tee girder with the exception that the top flange is intended to act as the structural deck and is therefore designed to support traffic loads. The top flanges can be upwards of 8 feet in width and are connected in the field using welded tie connections combined with a grouted shear key. Such girders are also known as side-by-side systems as shown in Fig. 1. Similar to adjacent box beams, Deck Bulb Tee girders are mostly used for single span bridges but are occasionally used for multi-span bridges. A primary advantage of using Deck Bulb Tee girders is to speed up construction by applying a 2 inch minimum wearing surface to the top of the girders in lieu of a concrete deck. This structure type, although common in the Northwest region, is rarely used in other parts of the country. It has been used extensively in cold regions like Alaska where the construction season is short and cast-in-place concrete decks are expensive. This is also true for fast track projects where construction schedule is a primary concern.

In this paper, the design of Oregon's First Continuous Deck Bulb Tee Girder Bridge, Upton Road over Bear Creek, is presented. This three-span structure with 2 inch asphalt wearing surface is supported by 17-ft tall integral abutments and integral piers. Unlike conventional precast concrete I-girder bridges in which the concrete slab provides continuity, the top flange of the Deck Bulb Tee girders and diaphragms are detailed to achieve the needed continuity. The design challenge is detailing the connection between the top flanges of the precast girders and the cast-in-place concrete pier diaphragm. Research has previously been conducted on the welded shear connectors and grouted shear key between girders for the load transfer/ load distribution to verify that the deck acts as an integral unit. However, research has not been conducted for the integral connection over the pier. The bridge has been in service for a few years and no distress was reported during bridge inspection.

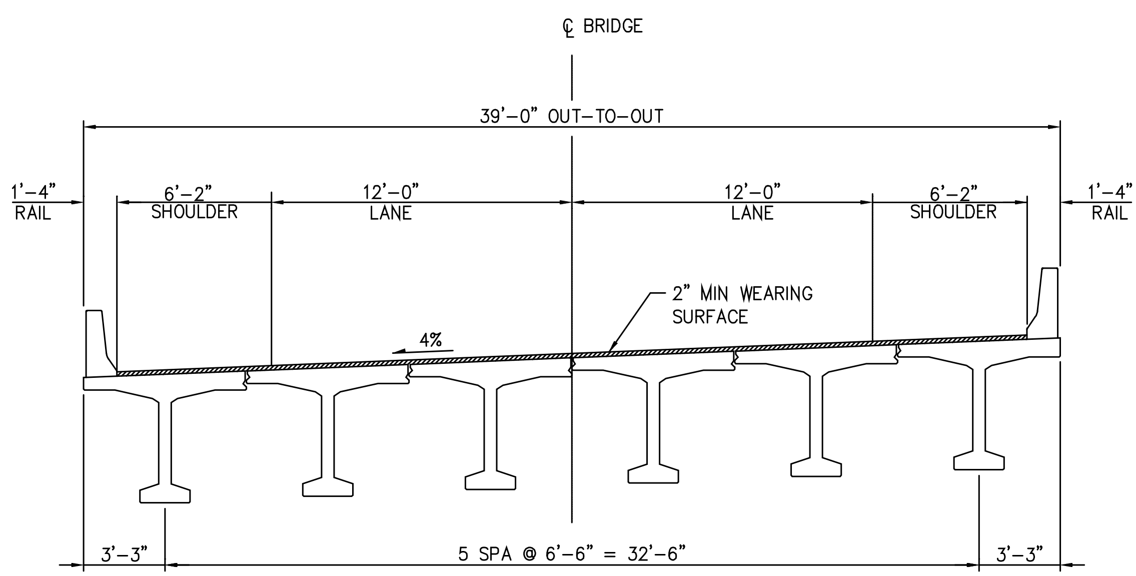

Fig. 1 Typical Section of Deck Bulb Tee Girder Bridge

The challenges for designing Oregon's First Continuous Deck Bulb Tee Girder Bridge were as follows:

- Curved alignment: Girders in each span placed parallel to chord;
- Detailing for continuity: Girders kinked at each pier location;
- Staged construction: Traffic to be maintained during construction;
- Very tall integral abutment: 17 feet from bottom of the pile cap to top of the girder;
- Very long cantilever wingwall: 23 feet from front face of abutment to end of wingwall; and
- Steep roadway grade: 5.6%.

DECK BULB TEE GIRDER BRIDGE

The main advantage to using Deck Bulb Tee girders is to speed up the superstructure construction. This structure type is typically used in rural areas with low to moderate traffic volumes where the speed limits are considerably less than that of a mainline. These lower demands tend to reduce the concerns of fatigue of the welded shear connections and minimize possible telescoping cracks in the asphalt wearing surface over the welded/grouted shear keys.

The Deck Bulb Tee girder is best suited for single span, straight bridges with span lengths ranging from 70 to 115 feet[1]. 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 similar cost to conventional I-Beam construction and a lower construction cost when compared to post-tensioned concrete box girders. The current average unit costs from the Washington Department of Transportation Structural Estimating Aids for Deck Bulb Tee girder, prestressed concrete girder, post-tensioned concrete box girder, and prestressed concrete slab bridges are shown in Table 1.

Table 1. Construction Costs (WSDOT)[1]

Girder Type	Span Range	Unit	Cost
Prestressed Concrete Deck Bulb Tee Girder	40 – 115 FT.	SF	$155
Prestressed Concrete Girder *	50 – 175 FT.	SF	$175
Post-Tensioned Concrete Box Girder *	50 – 200 FT.	SF	$250
Prestressed Concrete Slab	13 – 69 FT.	SF	$130

*Water crossing with piling.

Oregon began using the Deck Bulb Tee girder about 37 years ago. Lostine River (Wolf) Bridge in Wallowa County was the first Deck Bulb Tee girder bridge designed in Oregon in 1975[2]. Since then this structure type has been designed and built throughout the state of Oregon with Upton Road over Bear Creek being the first continuous Deck Bulb Tee girder bridge built in this state.

Upton Road over Bear Creek Bridge is located in Jackson County, Oregon. This structure is a 285 foot long (85'-100'-100' per span), continuous three-span Deck Bulb Tee girder bridge supported by integral abutments and multi-column bents. The span lengths selected fall into the economical range shown in Table 1. The elevation view of the bridge is shown in Fig. 2. The 64.5 ft wide bridge carries three lanes of traffic with a sidewalk on each side. A 2 inch minimum asphalt concrete wearing surface with a waterproofing membrane was placed on top of the Deck Bulb Tees with a maximum build-up at the abutments and piers of approximately 7 1/2 inches due to the sagged vertical profile of the roadway. Waterproofing membrane system was specified per ODOT Construction Specifications. The typical deck section is shown in Fig. 3.

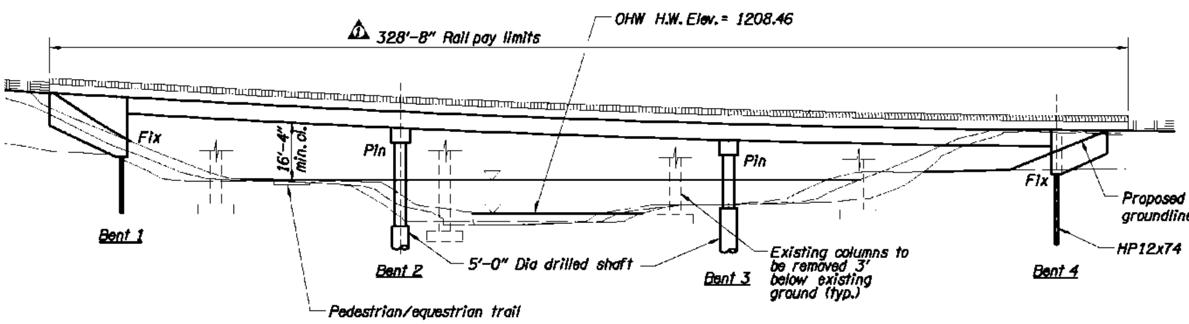

Fig. 2 Upton Road over Bear Creek - Elevation

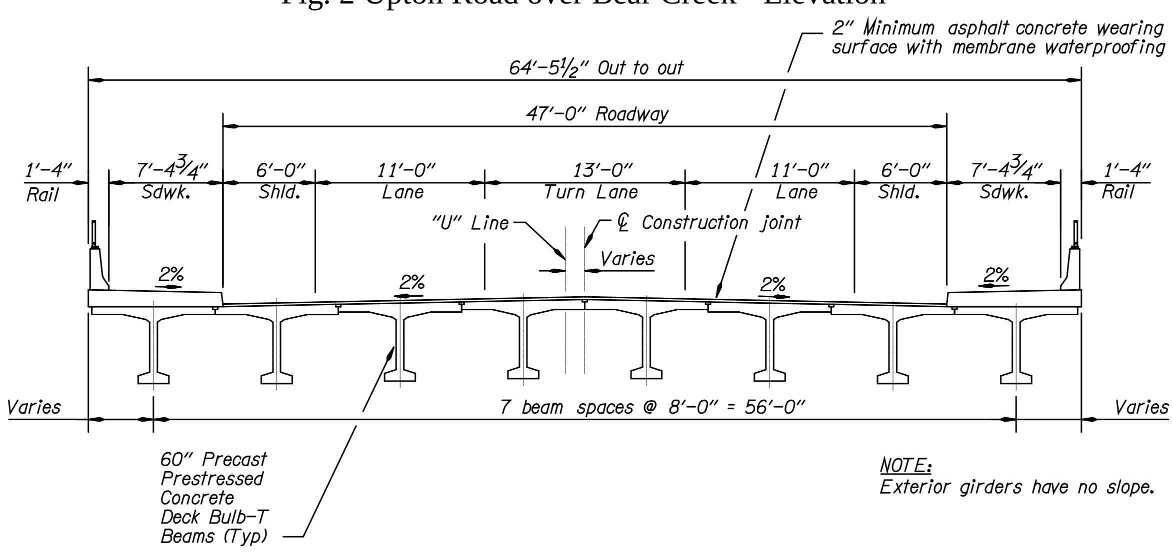

Fig. 3 Upton Road over Bear Creek - Typical Section

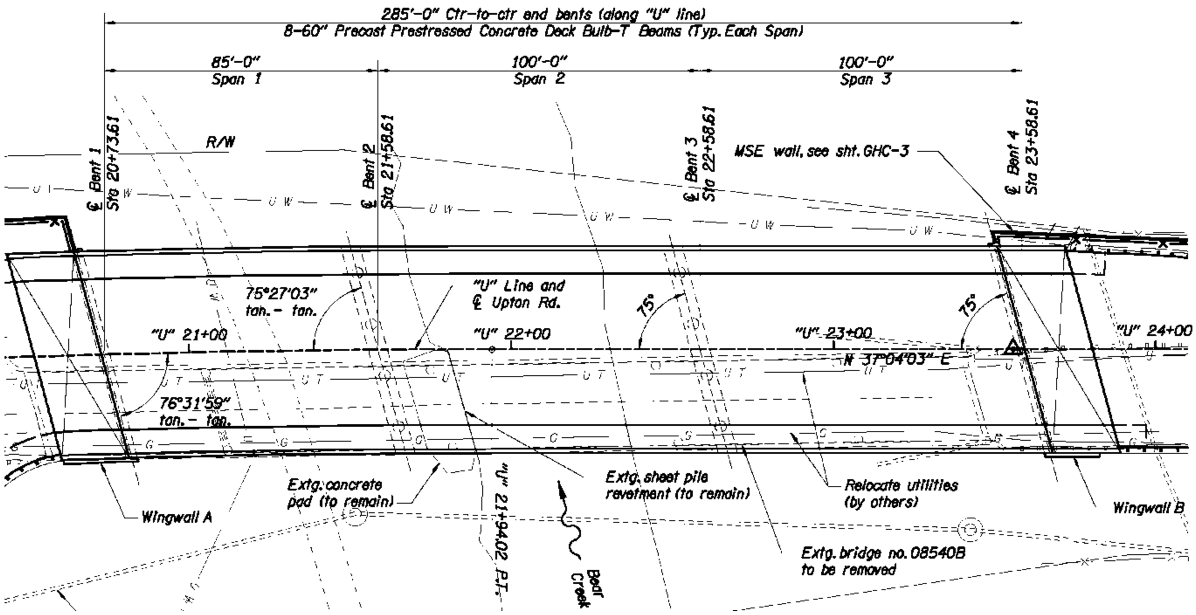

Fig. 4 Upton Road over Bear Creek - Plan

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 plan view of the bridge is shown in Fig. 4.

The girder section at mid-span and at the girder end is shown in Fig. 5. Figure 6 shows the pour sequence for the girder where the top flange portion is limited to a maximum concrete strength of 6000 psi. This limitation is required to ensure adequate air entrainment and proper workability of the concrete. Higher strength concretes are generally less workable and therefore are more difficult to achieve an acceptable finish suitable for either a deck surface or as in this case application of the waterproof membrane. The top flange or lower strength concrete is poured immediately following the web/bottom flange pour and integrated with the use of a stinger to ensure a monolithic pour. The pour sequence/use of multiple concrete strengths is not intended to form a cold joint, but rather to achieve proper finishing of the top flange. Per ODOT Bridge Design and Drafting Manual, the maximum concrete strength for the web and bottom flange is 9000 psi[3]. A concrete strength of 8000 psi was used for the design of the web and bottom flange portion of the girders for the bridge being highlighted. Furthermore, ODOT required entrained air from 4 to 7 percent for the girder top flange. Entrained air was not required for the web and bottom flange[4].

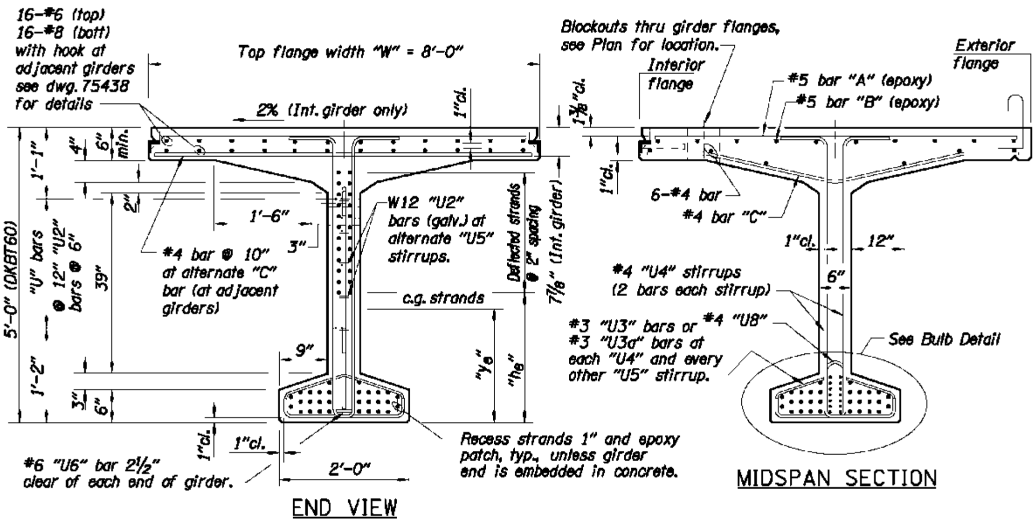

Fig. 5 Typical Girder Section

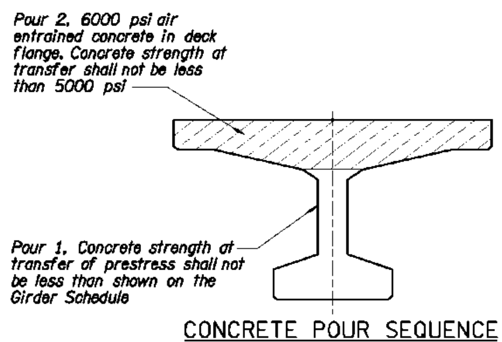

Fig. 6 Concrete Pour Sequence

Like other side-by-side girders, transverse shear connections between adjacent girders are critical for the performance of the system. Since transverse PT or transverse tie bars (typically used in precast adjacent box girders and prestressed slabs) are not feasible for Deck Bulb Tee girders, the welded tie connection shown in Fig. 7 combined with grouted shear keys are typical for this type of design. The shear connectors are spaced at 5'-0" with a maximum distance of 7'-6" from the first shear connector to the girder end. The grouted shear keys are continuous along the full length of the girder.

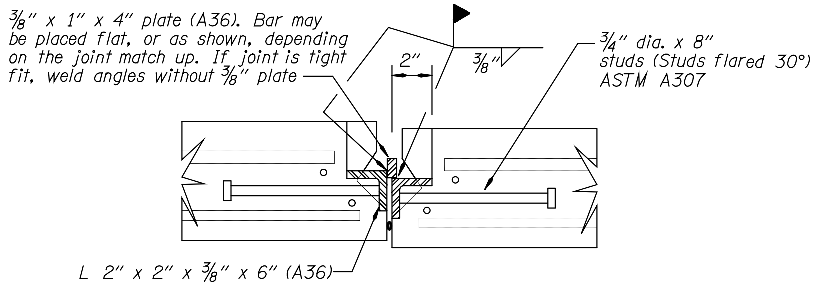

Fig. 7 Flange Shear Connector

Design of a Deck Bulb Tee girder is similar to that of a Bulb Tee girder with a few minor exceptions. When AASHTO LRFD is used for skewed bridges[5], the correction factor for load distribution for shear at the obtuse corner is not defined for Deck Bulb Tee girder bridges. Therefore, either a refined method of analysis or engineering judgment must be used to magnify shear as necessary. The skew angle for Upton Road over Bear Creek Bridge is about 15 degrees which in our case had minimal impact.

Secondly, the design of a Deck Bulb Tee girder needs to account for the lower concrete strength used in the top flange and the higher concrete strength used in the web and bottom flange. Typical prestressed concrete girder design programs may not have the capability to handle the different concrete strengths. Therefore, the transformed section shall be used 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 need to 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.

CONTINUITY AT PIERS

Conventional beam slab systems achieve continuity at the piers using a reinforced concrete deck. For Upton Road over Bear Creek Bridge, the top flanges of the Deck Bulb Tees and diaphragms were detailed to provide the needed continuity at the piers. As such, the reinforcement projecting from the girder top flange as shown in Fig. 8 must be carefully detailed to avoid interference with reinforcement from the adjacent span, particularly if the girders are kinked like those framing into Bent 2 of the Upton Road over Bear Creek Bridge. If the girders from adjacent spans are parallel, the reinforcement projecting from the top flange can simply be staggered with enough lap length to provide the continuity; an example of this layout is shown in Fig 9. However, the curved alignment for Upton Road over Bear Creek did not allow for a conventionally staggered layout. Therefore, #6 and #8 U bars were provided, overlapping the bars projecting from the girder top flange. Mechanical anchorages were used to develop the second row of projecting steel to ease fabrication. 5000 psi HPC was used for the pier diaphragms.

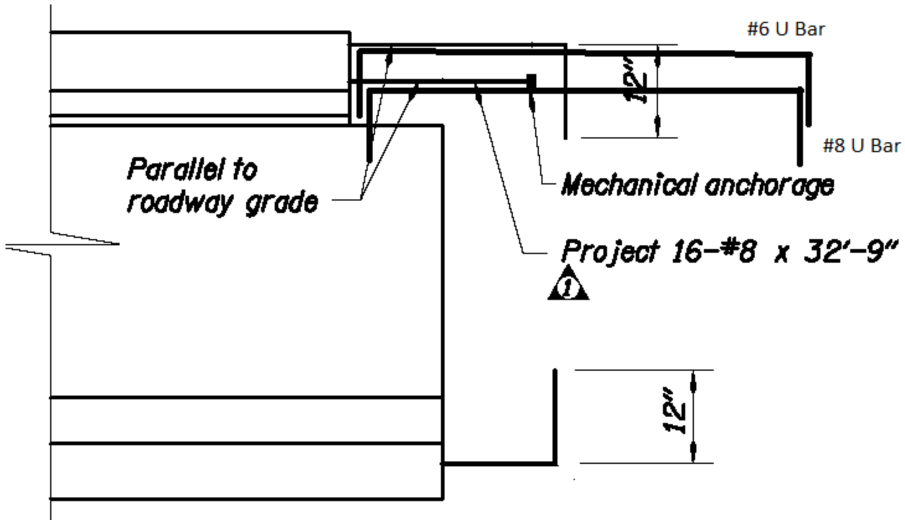

Fig. 8 Elevation View at Girder End

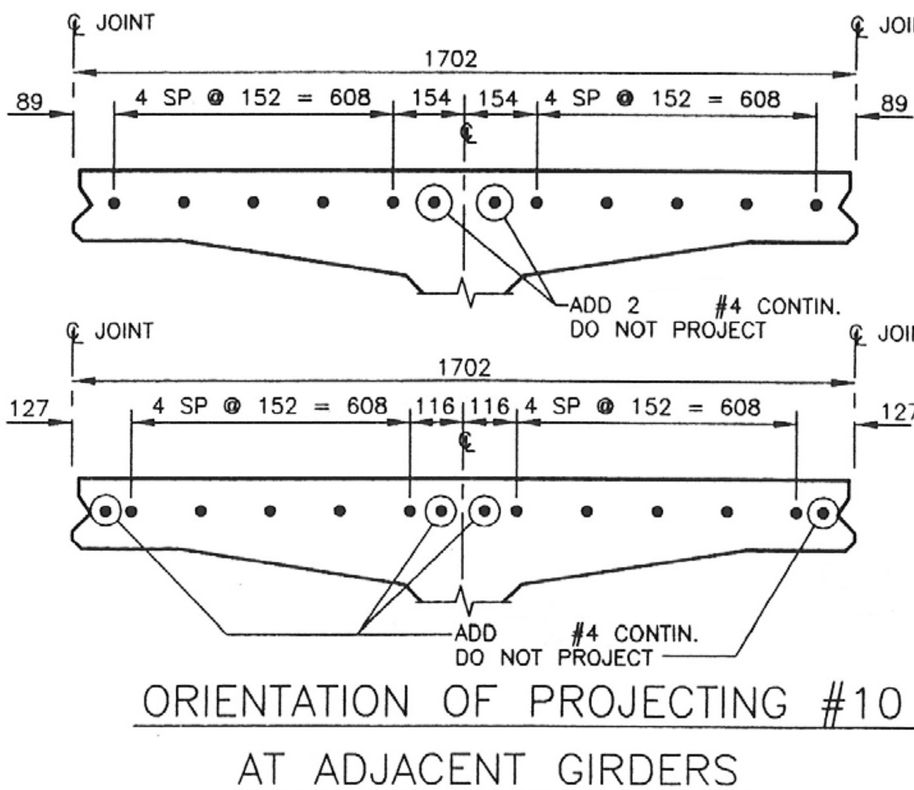

Fig. 9 Staggered Top Flange Rebar Layout at Adjacent Girders (Example Bridge)
(All dimensions are in mm. 1 inch = 25.4 mm)

INTEGRAL ABUTMENTS

By eliminating expansion joints and bearings, integral abutments reduce maintenance costs. This type of bridge can increase design efficiency, add redundancy and capacity for a seismic event, provide a stiffer longitudinal response at abutments, enhance load distribution for girders at bridge ends, reduce tolerance problems, and provide greater end span ratio ranges.

Normally, the typical integral abutment height from bottom of the pile cap to top of girder or top of slab is less than 10 feet. Due to the site constraint, the west abutment for this bridge is 17.5 feet tall while the east abutment is 13.5 feet tall. The elevation front view and cross section of the abutment are shown in Fig. 10 and Fig. 11, respectively.

As a result of the tall abutments, longer cantilever wingwalls were required to retain the embankment. For the SW corner of the bridge, a 23 foot long cantilever wall was used (see Fig. 12). This wingwall is designed for both in-plane and out-of-plane bending under lateral soil pressure.

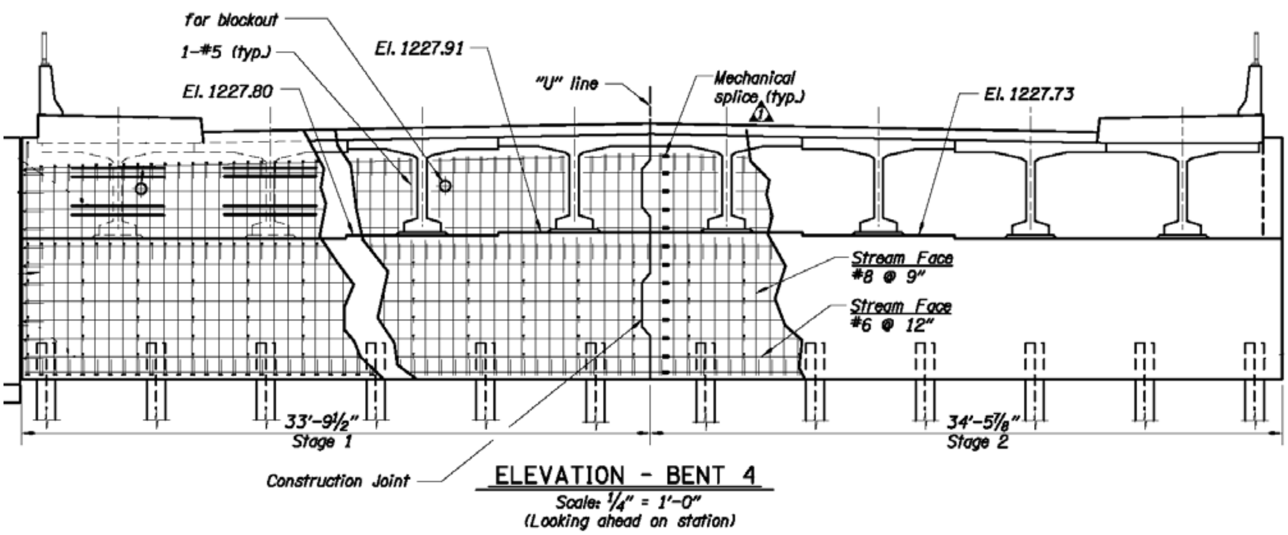

Fig. 10 Abutment Elevation

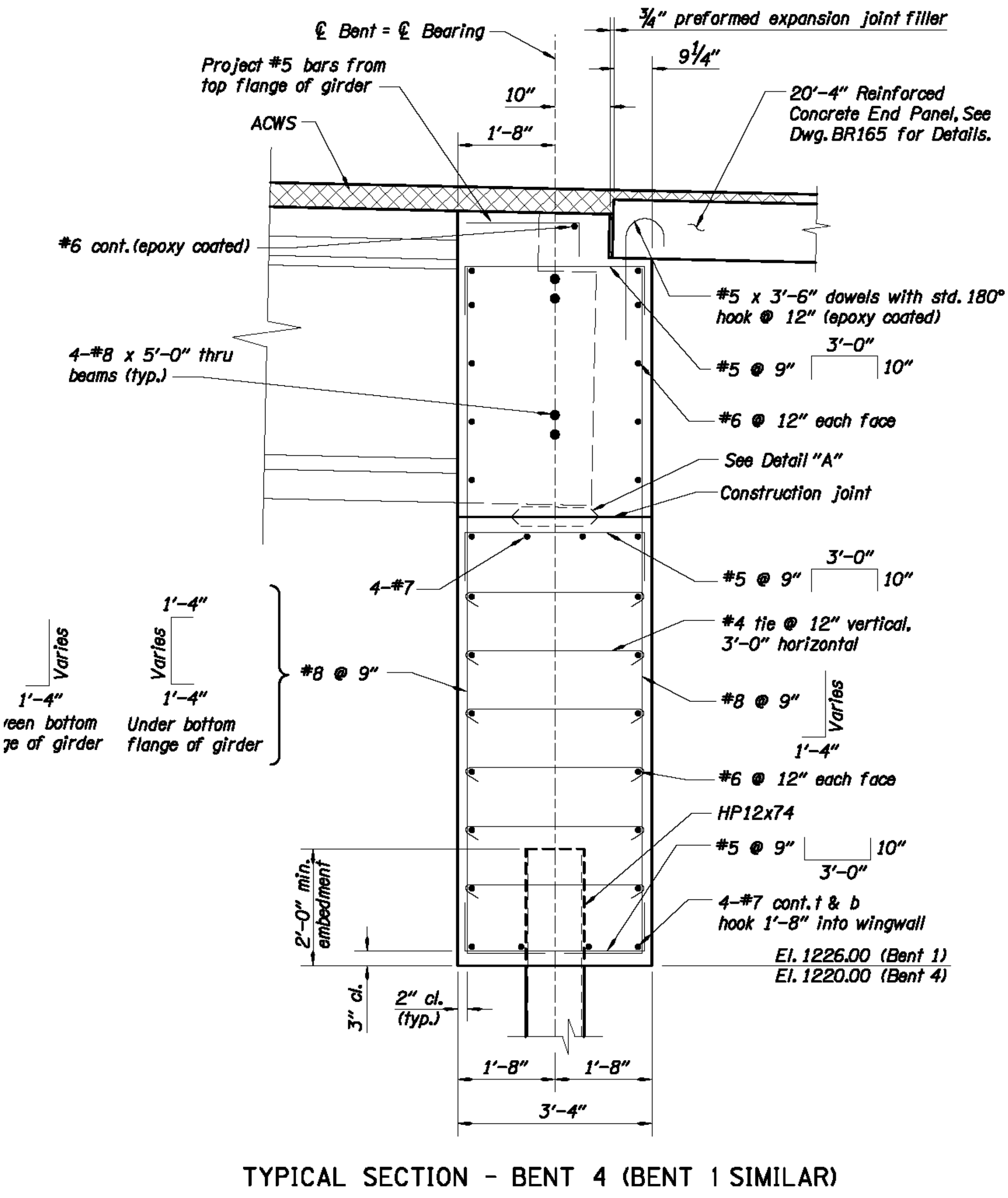

Fig. 11 Abutment Section

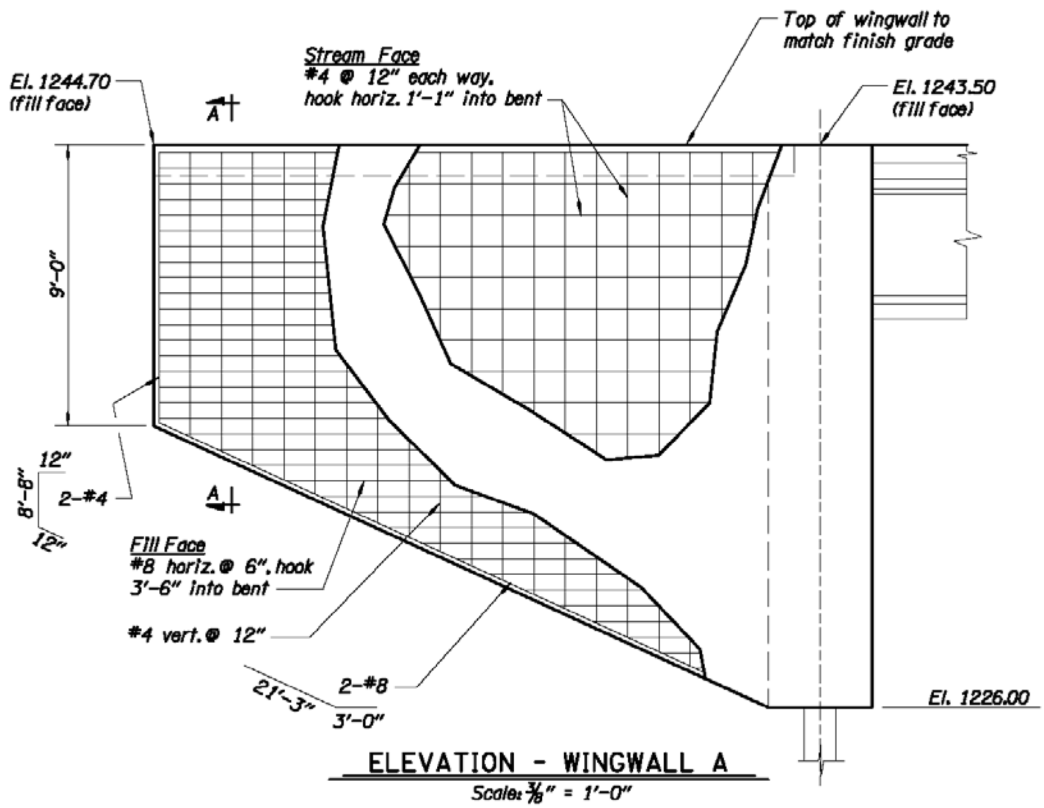

Fig. 12 Wingwall Elevation

CONSTRUCTION

Construction started in August, 2007 and was completed in January, 2009. The structure was built in two stages as shown in Fig. 13 in order to maintain traffic during construction. The completed pier diaphragm is shown in Fig. 14. The bid construction cost, excluding mobilization, was $140/SF.

Fig. 13 Staged Construction

Fig. 14 Pier Diaphragm

CONCLUSIONS

The use of Deck Bulb Tee girders is advantageous when an accelerated construction schedule is of the utmost importance. This structure type is typically used in rural areas with low to moderate traffic volumes where the speed limits are considerably less than that of a mainline. These lower demands tend to reduce the concerns of fatigue of the welded shear connections and minimize possible telescoping cracks in the asphalt wearing surface over the welded/grouted shear keys. The Deck Bulb Tee girder is best suited for single span, straight bridges with span lengths ranging 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. Although continuous spans require careful consideration with regards to detailing, the use of integral abutments and providing continuity at the piers offers many benefits such as eliminating expansion joints, reducing the cost for maintenance, providing stiffer longitudinal response at abutments, enhancing load distribution of girders at the bridge ends, reducing tolerance issues, and providing greater end span ratio ranges. In addition to the benefits reported herein, Deck Bulb Tee girder bridges are considerably more cost effective than a post-tensioned concrete box girder bridges and are similar in cost to a standard prestressed concrete girder structure with a cast-in-place concrete deck.

ACKNOWLEDGEMENT

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