DEVELOPMENT OF BULB-TEE STANDARDS FOR THE IOWA DEPARTMENT OF TRANSPORTATION

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ABSTRACT

To develop economical bridges for the rebuilding of the I-235 freeway, the Office of Bridges and Structures at the Iowa Department of Transportation created a partnership with the local precasting industry to create a new bulb tee shape. A new shape was needed because of the longer spans and shallower depths required for the reconstruction. After reviewing other states bulb tee shapes, the state based its design on a shape recently developed by the Wisconsin DOT, with modifications for Iowa's needs. The new shape was designed using AASHTO's LRFD specification.

Two new sections were developed from the Wisconsin shape, a 45-inch deep (BTC) and a 54-inch (BTD) section. Also, the existing shallower sections, the 32-inch deep Iowa A section and the 39-inch deep Iowa B section were lengthened. High performance concrete with release strengths up to 8,000 psi and final concrete strengths of up to 9,000 psi were used in the section. The BTC was designed for spans up to 120 ft and the BTD for spans up to 135 ft.

The original section used a 48-inch top flange, which was later modified to 34 inches as requested by the precasters and for improved constructability. In 2002 on I-235, this section was used and future plans are currently being developed by the state, cities and counties in Iowa to further use the section.

Keywords: Bulb-Tee, High Performance Concrete, I-235 Freeway,

INTRODUCTION

As part of the reconstruction of the I-235 freeway in Des Moines, Iowa the Office of Bridges and Structures and the Iowa Prestressing Association worked together and developed a new prestressed beam shape. The requirement of longer spans and shallower beam depths for the reconstruction of I-235 in Des Moines necessitated this beam design. The new beam shape selected was a modified version of a bulb tee shape developed by the Wisconsin DOT.

Two depths were designed from the new shape to use in the reconstruction, a 45-inch deep section (BTC) and a 54-inch deep section (BTD). High performance concrete was used with release strengths of up to 8,000 psi and final strengths of 9,000 psi. The BTC was designed for spans up to 120 feet, and the BTD was designed for spans up to 135 ft. Currently the BTD section has been used on a number of bridges on I-235, and with the release of the standard beam sheets, will be used throughout the state. This report is an overview of the development of this new section.

BEAM DEVLOPMENT

The Iowa Department of Transportation has used prestressed beams in its bridge plans since the late 1950s and developed standard prestressed beam sections designated as A (32 in), B (39 in.), C (45 in.), and D (54 in). See Figure No. 1. Design work was completed in the early 90's to extend the D section using higher strength concrete (6,000 psi release and 7,500 psi final) to a maximum of 120 ft.

The Iowa Department of Transportation has a working relationship with the precasting industry through the Iowa Prestressing Association to improve the efficiency and economy of the prestressed beams that are used in Iowa. Through this partnership the association developed an 1800 mm (72-inch) deep section (see Figure No. 2), which was added to the standards, to extending the span lengths for prestressed concrete to 140 ft.

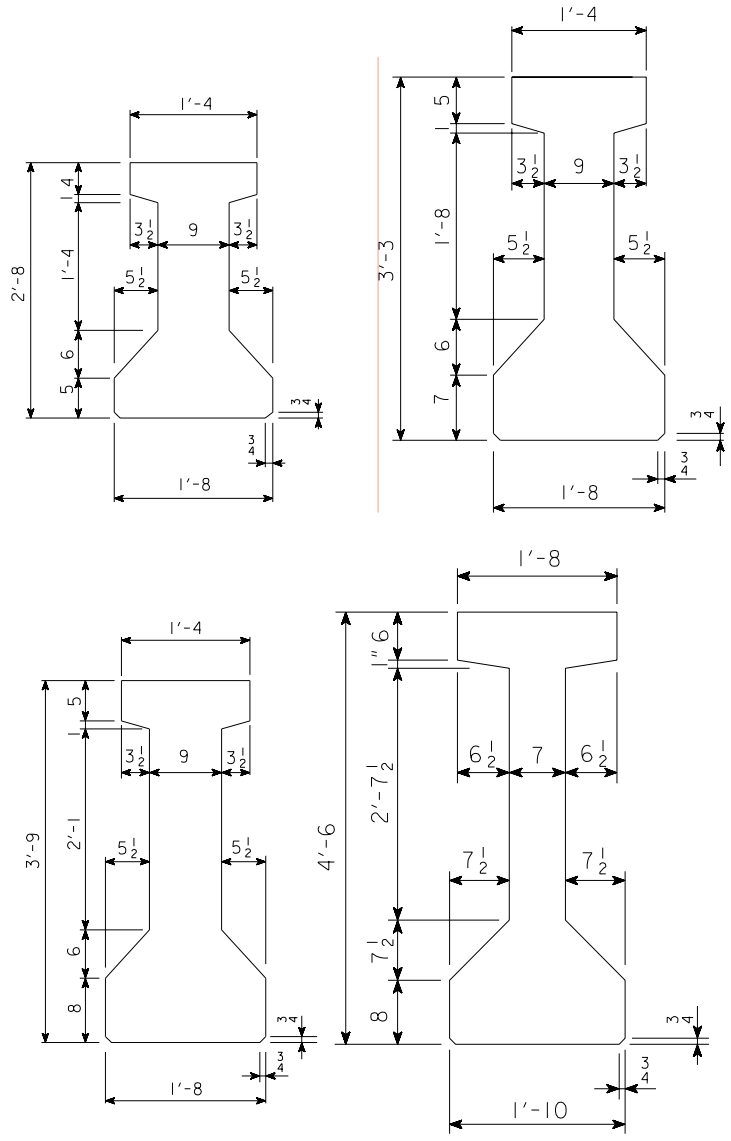

Figure No. 1
(Standard A, B, C, and D sections)

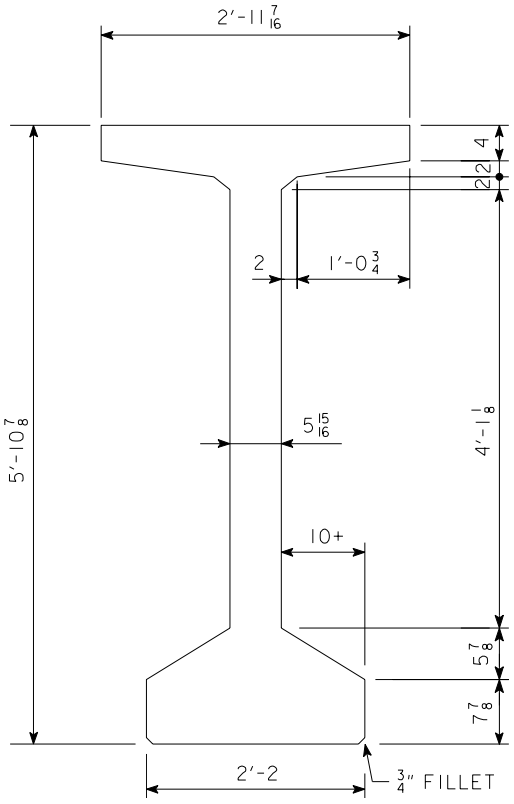

Figure 2
(BT Section)

The partnership continued with the development of the new sections for the I-235 reconstruction. Due to geometric requirements for the bridge replacements, the new sections were required to meet the depths and span lengths shown in Table No. 1. To meet these limits, the precasters initially proposed to modify the existing 1800 mm (BT), and develop a family of beams (See Figure No. 3). Current Iowa standards depths would be used.

Table 1 (Depths and Maximum Span Lengths)

Section	Depth (inch)	Maximum Span (feet)
A	32	70
B	39	85
C	45	120
D	54	145

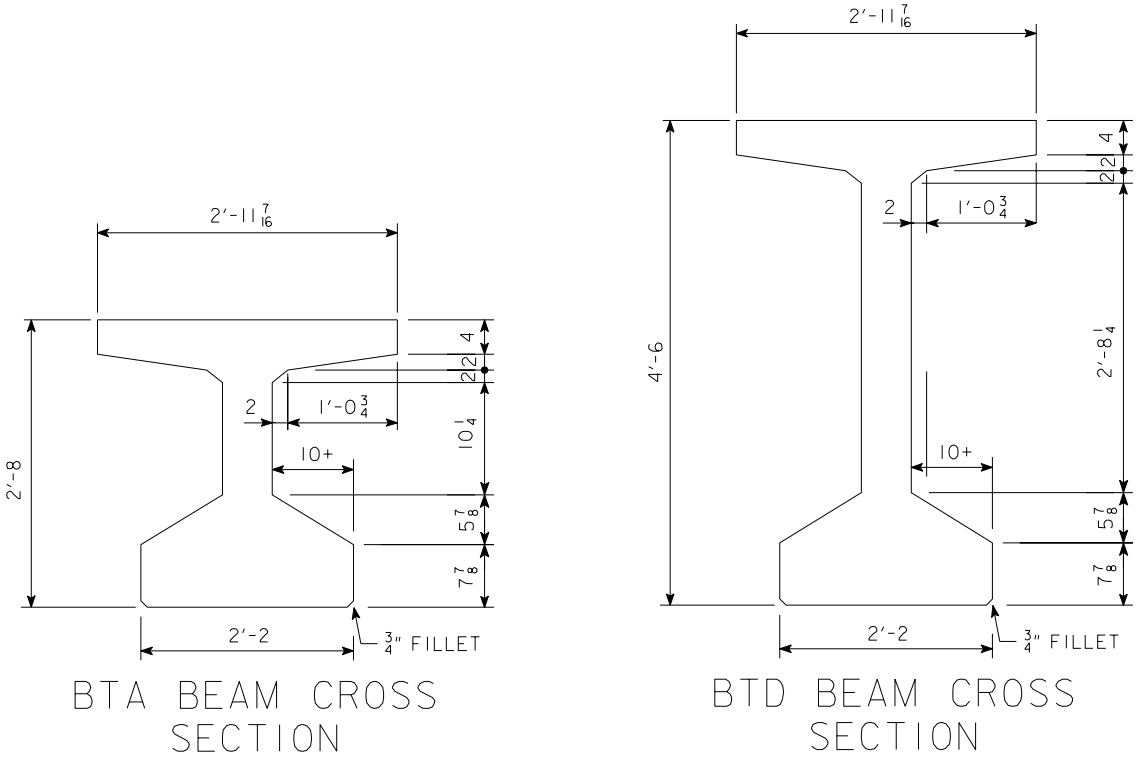

Figure 3
(Proposed Bulb-Tee)

After initial review of the modified 1800 mm section and a review of what had been done with bulb tee shapes by Nebraska[1], Washington, Florida[2], Wisconsin and New England States[3], a decision was made to adopt the Wisconsin bulb-tee shape with minor modifications (See Figure 4 and Figure 5).

The decision was based on:

1. Larger bottom bulb used by Wisconsin, which allows more room for strands.
2. Wider top flange, which provides a more stable section.
3. Curve fillet, which provides more strength at the flange-to-web interface and a more attractive beam.

Initially the proposed section was to be used for all beam depths (A to D).

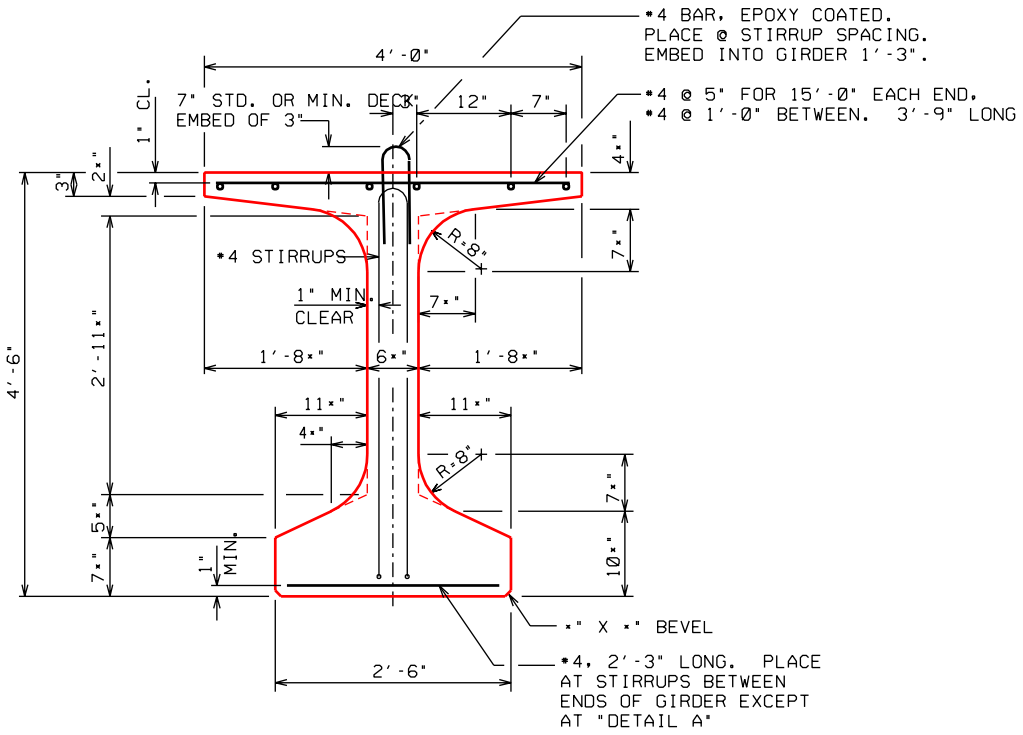

Figure No. 4
(54-inch Wisconsin Shape)

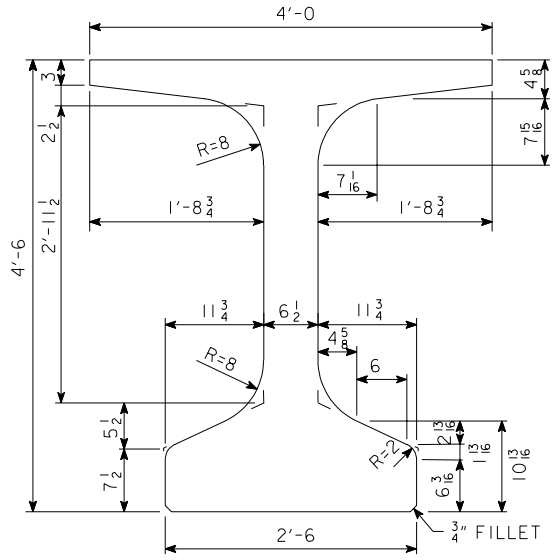

Figure No. 5
(Proposed 54 inch Iowa Bulb-Tee)

However, after preliminary design work, the shallower sections A and B were reviewed again. Because of the limited use of the shallower sections on the I-235 reconstruction and the shorter span lengths, it was felt that the bulb tee shape was not economical for these sections. A preliminary design was completed using the existing standards (A and B with 0.6 inch strands and higher strength concrete (8,000 psi release and 9,000 psi final) to determine if a 70 foot span for the A and 85 foot span for the B was feasible (See Figure 6 for existing A and B sections). Design calculations confirmed these span lengths were acceptable.

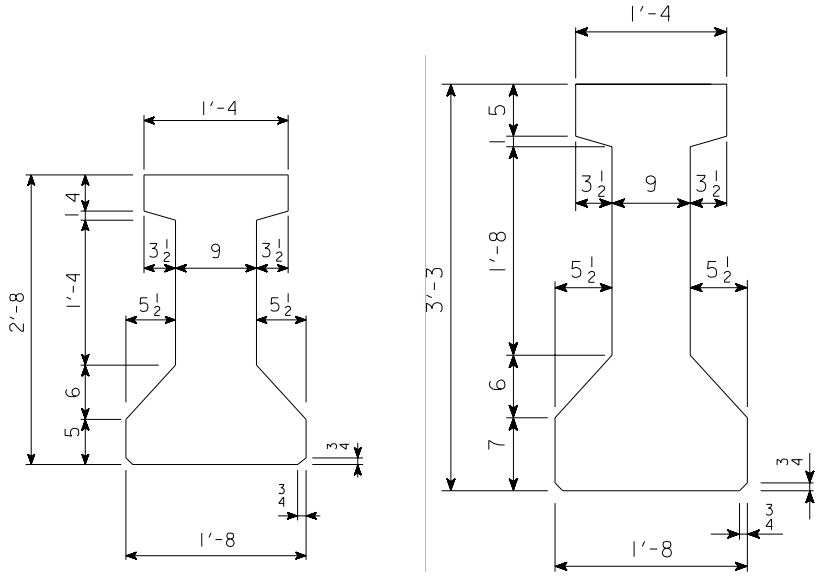

Figure No. 6
(Existing A and B Sections)

Therefore, only the BTC and BTD sections were adopted (See Figure No. 5 for details of BTD).

DESIGN AND STANDARDS

To save design time, the Office of Bridges and Structures has assembled standard beam sheets for use in bridge plans. Span lengths that were standardized for 30 ft to 115 ft using 5-foot intervals for the BTC and 50 foot to 135 foot using 5-foot intervals for the BTD. Equivalent metric standards were also developed. The following design criteria were used for the standards:

1. AASHTO LRFD Bridge Design Specifications, Second Edition 1998.
2. 0.60 inch diameter ASTM A416 Grade 270 Low Relaxation Strands, stressed to 72.6 % of GUTS.

3. 9.25 foot maximum beam spacing.
4. 8.0-inch cast-in-place slab with 0.5 inch wearing surface.
5. 1.5-inch slab haunch for weight and 0.5-inch slab haunch for composite calculations.
6. 20 pounds per square foot for future overlay.
7. Use of strands in the transformed section.
8. Use of draped strands to reduce release stresses.
9. Maximum release compressive strength of 8,000 psi and maximum final compressive strength of 9,000 psi.

Standard detail plan sheets are available on the web at the following web site:

http://www.dot.state.ia.us/bridge/

FABRICATION AND CONSTRUCTION

In 2002, two overpasses were constructed for the I-235 Freeway in West Des Moines (28th Street and 42nd Street overpasses) used the BTD. See Figure 7 for casting photo.

Figure 7
(Casting of BTD)

Figure No. 8 shows the new beams in-place on the 28th Street bridge and Figure No. 9 shows the same site with the formwork in place. Figure No. 10 is a photo of the completed structure.

Figure 8
(Beams Erected 28th St.)

Figure 9
(Formwork in Place 28th St.)

Figure 10
(Completed 28th St. Bridge)

After fabrication and construction of the two bridges the following changes to the standards were discussed:

1. Top Flange Width
2. Wider Beam Spacing
3. Edge Bars in Top Flange
4. Epoxy Coating of Stirrups

MODIFICATIONS TO SECTIONS

1. Top Flange Width

In preliminary review of existing bulb tee designs, a trend towards a wider top flange was noted. In discussions with other state DOT's, the use of wide top flanges had two main benefits. One was the increased lateral stability for longer and deeper spans preventing the beams from tipping over during handling and erection. The second benefit was a reduction in the span length of the slab between beams, making the slab design more economical.

The large flange has other benefits.

1. The location of the neutral axis is higher in the section providing more efficient use of the prestressing force to resist externally applied loads.
2. In addition, the larger cross section allows for more strands to be used at release.
3. The larger work area for construction workers before the formwork is in place.

Some disadvantages of the wide top flange observed during the casting and construction of the two overpasses.

1. Heavier sections increased the overall cost of fabrication of the beam per foot.
2. Increased slab quantity and haunch weight. With longer spans haunch thicknesses were significant, (over 3 inches), and the wide flange required larger quantities of concrete in the haunch.
3. Reinforcing bars were provided along the flange edge. These additional bars caused interference with the slab steel and handling and safety problems. See Figure No. 11.

Figure No. 11
(Top Flange Reinforcing Detail)

4. Spalling of the narrow flange edge occurred during form removal and edge cracking of the flange was encountered at the bridge site.
5. Concern with possible deck replacements in the future and the difficulty in removing the slab from around the flange without damaging the flange.
6. For longer and heavier beams, some precasters would require outside trucking firms to haul the beams.

7. Heavier sections would require some smaller contractors to rent larger cranes for handling the section.
8. The wide top flange was not necessary for stability and handling of the BTC and BTD used by the Iowa Department of Transportation. The current maximum section depth was 54 inches, and future plans included a 63-inch deep section. Design calculations showed that a four-foot flange was not needed for these beam depths, and the office did not expect to use larger standard depths developed by other states.

After considering the above points, the office decided to reduce the top flange width to 34 inches. This reduction was based on using the new section for shallower depths and shorter spans (135 ft. and less). If a 63-inch section was developed in the future, stability calculations showed a 34-inch flange width could still be used.

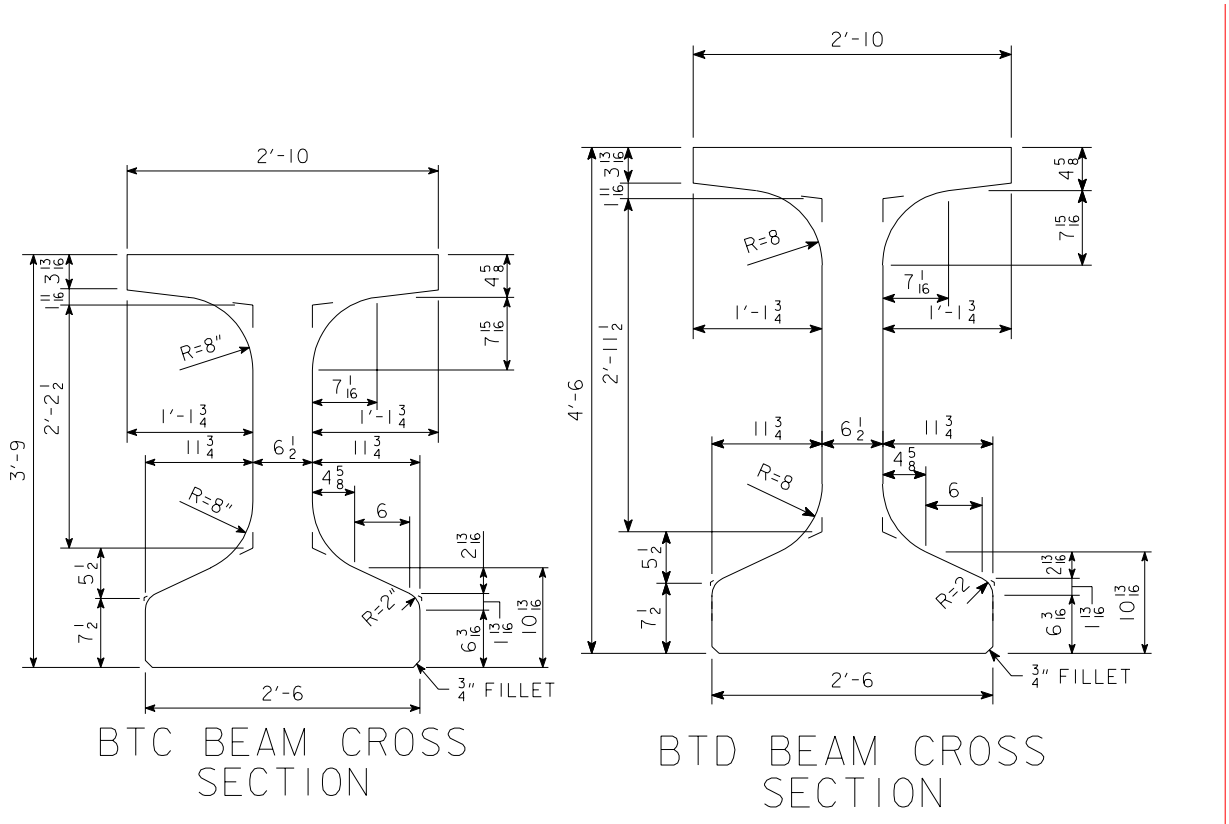

Figure 12
(Final BTC and BTD Section)

2. Wider Beam Spacing

Due to higher cost of the section, the office decided to use the widest possible beam spacing and eliminate beam lines

3. Edge Bars in Top Flange

With adoption of the 34-inch top flange, the edge bars were removed and only the center stirrup used for the composite connection.

4. Epoxy Coating of Stirrups

To reduce the corrosion in the slab the center bar was epoxy coated.

CONCLUSION

Development of the new bulb tee sections will provide the Iowa Department of Transportation with economical sections, and will increase the use of prestressed concrete in new and replacement bridges.