C5.4 Pretensioned Prestressed Concrete Beam

July 2025 ~ PPCB Updates

The Bureau has removed designs of the A-D beams from the manual. State projects no longer use these beams. The signed H40 and H44 three span PPCB H-standards, which are based on the A to D beams, are no longer used for state projects. These beam standards were eliminated due lack of use in bridge projects. The last version of the A to D beams was based on the 2017 AASHTO LRFD Bridge Design Specifications, 8th Edition.

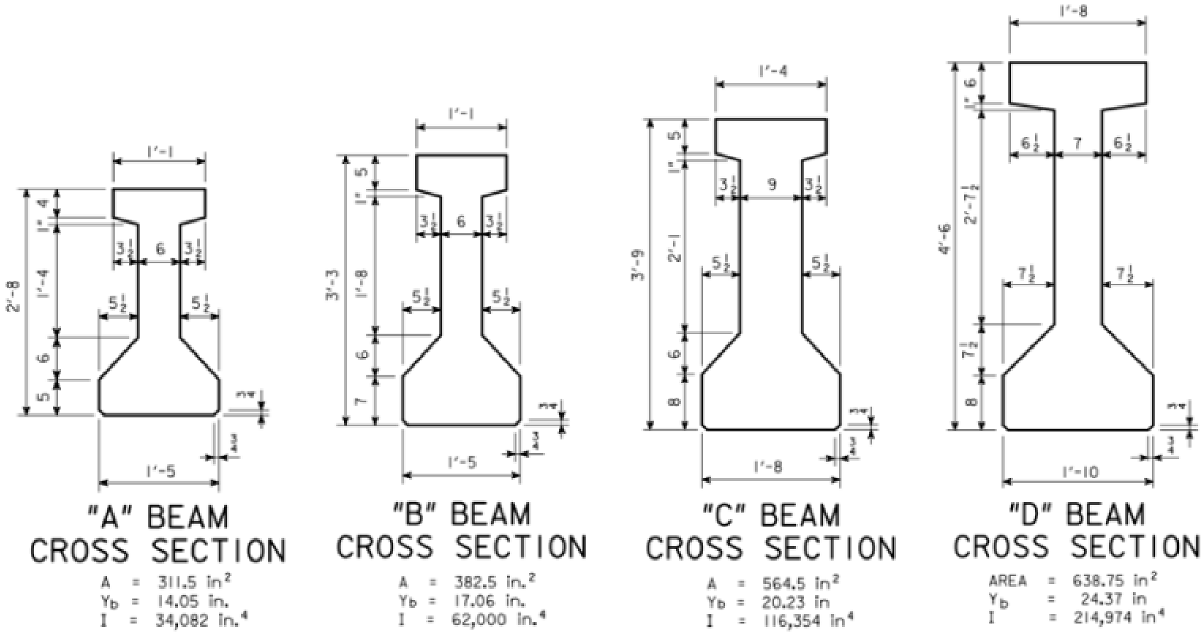


Figure C5.4.1. A to D beam shapes

August 1, 2023 ~ PPCB Updates

The Bureau has updated the designs of the A-D and BTB-BTE beams to meet the AASHTO LRFD Specifications, 8th Edition, 2017. These designs and checks have been performed with LBC (LEAP CONSPAN) software. To meet design requirements, some partial strand debonding was introduced for some of the longer BT beams.

Commentary Prior to August 1, 2023 ~ PPCB Updates

The Bureau has redesigned the LXA-LXD, I-shapes to create an A-D beam series that meets the AASHTO LRFD Specifications, and the series has been updated to the fourth edition. The Bureau also has checked and updated the BTC and BTD shapes to the fourth edition and designed and updated the additions to the BT-series, BTB and BTE, to the fourth edition. These designs and checks have been performed with CONSPAN software. All PPCB superstructures and supporting substructures are to be designed by LRFD, and that method has been used to design the transverse reinforcement and the longitudinal deck reinforcement above piers on standard sheets.

This article now covers only the PPCB LRFD superstructure types. The transition to the AASHTO LRFD Specifications is complete, and the Standard Specifications article, which covered standard I and bulb tee shapes used in structures during and since the 1990s, has been withdrawn. The recent series of beams and their status are summarized in Table 5.4.

Table C5.4. Pretensioned prestressed concrete beam series, AASHTO design specifications, and series status

Beam Series	AASHTO Specification	Series Status
LXA-LXD	Standard, 14th Edition	Replaced by A-D series
AM-DM	Standard, 15th Edition	Not to be maintained, for metric projects only
BT	Standard, 15th Edition	Not to be maintained
BTM	Standard, 15th Edition	Not to be maintained, for metric projects only
BTB-BTE	LRFD, 4th Edition	Current
BTCM-BTDM	LRFD, 2nd Edition	Not to be maintained, for metric projects only
A-D	LRFD, 4th Edition	Current, replaces LXA-LXD series

C5.4.1.3.2 Limit states

2011 ~ Strength V Limit State During Construction and Other Revisions

Based on the description in the AASHTO LRFD Specifications of the Strength V limit state it seemed that it was not intended to be checked during construction. However, a steel plate girder example by M.A. Grubb and R.E. Schmidt distributed nationally by the U.S. Department of Transportation (USDOT) and National Steel Bridge Alliance (NSBA) includes Strength V during construction. The description of Strength V notes: "…plus 1.35 times the design live load (or any temporary live loads acting on the structure when evaluating the construction condition), plus 0.4 times the wind load on the structure, plus 1.0 times the wind on the live load. For evaluating the construction condition under the STRENGTH V load combination, the load factor for temporary dead loads that act on the structure during construction is not to be taken less than 1.25 and the load factor for any non-integral wearing surface and utility loads may be reduced from 1.5 to 1.25." Based on the example and other sources it is clear that Strength V should be checked during construction when appropriate, and articles in the design manual have been revised with respect to construction limit states. (There are several other changes, also.) The steel example is available at the following URL:

http://www.virginiadot.org/business/resources/SteelDesignExample.pdf

C5.4.1.4.1.6 Moment

15 March 2012

In the past the Iowa DOT has designed PPCB superstructures by designing the beams for simple spans and detailing for continuity but then also checking the beams in the continuous condition. Generally, the beams and deck were adequate for all continuity checks near and at a pier. With development of longer beams, however, service checks at the transfer points and compression checks for negative moment at continuity diaphragms began to fail under some conditions. It also was difficult to place enough tension reinforcement in the deck. As a result, the Bureau has decided not to check the continuous condition for concrete compression, taking full advantage of the exception for simple spans in the AASHTO LRFD Specifications [AASHTO-LRFD 5.12.3.3.1].

In order to avoid construction difficulties, the Bureau is limiting the reinforcing in the deck so that longitudinal bar spacing is not too close and bars are not too large. In unusual cases these limitations may result in less reinforcement in the deck than would be required for the negative moment at the strength limit state. The Bureau is willing to accept that condition on a case-by-case basis and intends to monitor field performance.

The continuity condition above a pier during service is difficult to determine accurately. Under typical Iowa DOT procedures and specifications, the designer has minimal control over the age of beams at the time the pier diaphragm and deck are poured. Effects of creep and shrinkage after the superstructure is continuous also are difficult to quantify even when the age of beams is known. Generally, creep and shrinkage effects are relieved at ultimate conditions by concrete cracking and mild reinforcement yielding, and therefore the Bureau considers the exceptions noted above to be reasonable, and the exceptions are permissible under the AASHTO LRFD Specifications.

C5.4.1.4.1.9 Deflection and camber

1 January 2015

The following example is intended to illustrate CONSPAN's camber calculation procedure and to demonstrate the use of the recommended camber deflection multipliers from the ISU camber research project. BDM 5.4.2.1.5 contains the research report reference. The prestressed beam standards will be updated to reflect the new camber values at some point in the future.

<u>BTE145 Camber Calculation Example</u>
End to End Beam Length = 146.333 ft
Harp Location = (0.35)*(146.333 ft) = 51.217 ft – assume harp points shifted 0.05*L towards beam ends
Beam Height = 63 in
Gross Beam Area = 807.4 in^2
Gross Beam Inertia = 422,790 in^4
Gross Beam C.G. = 28.750 in from bottom of beam
Concrete Unit Weight = 0.150 kcf
Initial Concrete Strength, f'_{ci} = 7.5 ksi
Initial Concrete Modulus, E_{ci} = (33,000)*((0.150 kcf)$^{1.5}$)*(7.5 ksi)$^{0.5}$ = 5250.3 ksi
28-day Concrete Strength, f'_c = 8.5 ksi
28-day Concrete Modulus, E_c = (33,000)*((0.150 kcf)$^{1.5}$)*(8.5 ksi)$^{0.5}$ = 5589.3 ksi
Strand Diameter, d_b = 0.60 in
Strand Area, A_p = 0.217 in^2
Strand Transfer Length = 60*d_b = (60)*(0.60 in) = 36 in
Strand Modulus, E_p = 28,500 ksi
Strand Ultimate Strength = 270 ksi
Strand Jacking Percentage = 72.6%
Modular Ratio, N = E_p/E_{ci} = (28,500 ksi))/(5250.2 ksi) = 5.428 – CONSPAN does not round N

Strand Layout (52 total strands, 42 straight strands, 10 draped strands)

Straight Strands:	12 strands at 2 inches from beam bottom
	12 strands at 4 inches from beam bottom
	12 strands at 6 inches from beam bottom
	6 strands at 8 inches from beam bottom
Draped Strands at Center:	2 strands at 2 inches from beam bottom
	2 strands at 4 inches from beam bottom
	2 strands at 6 inches from beam bottom
	2 strands at 8 inches from beam bottom
	2 strands at 10 inches from beam bottom
Draped Strands at Ends:	2 strands at 52 inches from beam bottom
	2 strands at 54 inches from beam bottom
	2 strands at 56 inches from beam bottom
	2 strands at 58 inches from beam bottom
	2 strands at 60 inches from beam bottom
Draped Strands at Transfer:	2 strands at 49.071 inches from beam bottom
	2 strands at 51.071 inches from beam bottom
	2 strands at 53.071 inches from beam bottom
	2 strands at 55.071 inches from beam bottom
	2 strands at 57.071 inches from beam bottom

Strand C.G. at Center = 4.846 in
Strand C.G. at Ends = 14.462 in
Strand C.G. at Transfer = 13.898 in

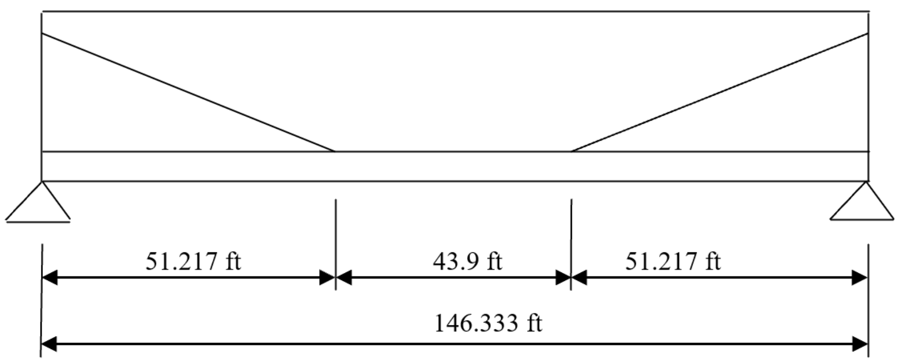
Transformed Beam Properties at Center:

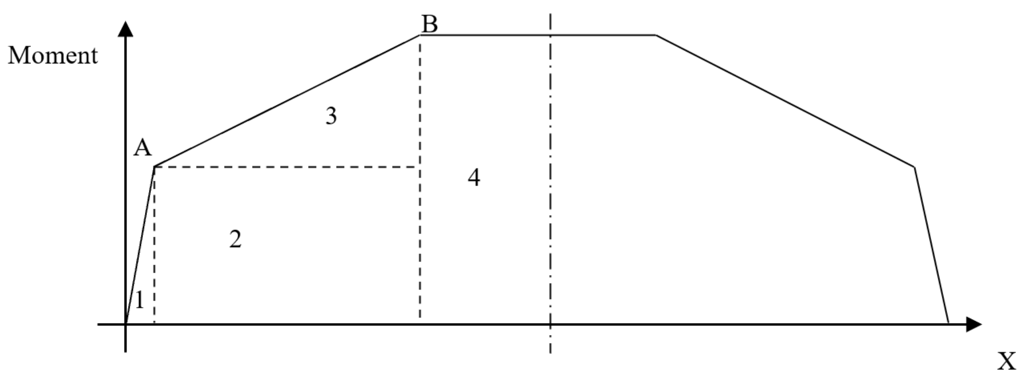
A_t = 807.4 in^2 + (5.428 – 1)*(52 strands)*(0.217 in^2) = 857.4 in^2

Y_{bt} = ((807.4 in^2)*(28.750 in) + (5.428 – 1)*(52 strands)*(0.217 in^2)*(4.846 in)) / (857.4 in^2) = 27.357 in

I_t = 422,790 in^4 + (807.4 in^2)*(28.750 in - 27.357 in)^2 + (5.428 – 1)*(52 strands)*(0.217 in^2)*
(27.357 in - 4.846 in)^2 = 449,677.9 in^4

Strand Force at Release, P_i = (52 strands)*(0.217 in^2)*(270 ksi)*(0.726) = 2211.9 kips





Moment-Area Method -- Point A is the transfer point, Point B is the harp point

M_A = (2211.9 kip)*(27.357 in – 13.898 in) = 29,768.77 kip*in

M_B = (2211.9 kip)*(27.357 in – 4.846 in) = 49,791.16 kip*in

Area		
1	(0.5)*(3 ft)*(29,768.77 kip*in)	= 44,653.160
2	(48.217 ft)*(29,768.77 kip*in)	= 1,435,347.539
3	(0.5)*(48.217 ft)*(49,791.16 kip*in – 29,768.77 kip*in)	= 482,705.305
4	(21.950 ft)*(49,791.16 kip*in)	= 1,092,913.560

Area * X		
1	44,653.160 * (2/3)*(3 ft)	= 89,306.319
2	1,435,347.539 * (3 ft + (0.5)*(48.217 ft))	= 38,909,795.803
3	482,705.305 * (3 ft + (2/3)*(48.217 ft))	= 16,964,372.225
4	1,092,913.560 * (51.217 ft + (1/4)*(43.900 ft))	= 67,969,961.002
Total		= 123,933,435.349 kip*in*ft^2

Center Deflection due to Prestress = (123,933,435.349 kip*in*ft^2)*(144 in^2/ft^2) / [(5250.3 ksi)*(449,677.9 in^4)]
= 7.559 in up

Center Deflection due to Self-Weight = 5wL^4 / 384EI = (5)*(0.841 klf)*(1/12 in/ft)*[(146.333 ft)*(12 in/ft)]^4 / [(384)*(5250.3 ksi)*(449,677.9 in^4)]
= 3.675 in down

Instantaneous Camber = 7.559 in – 3.675 in = 3.884 in, close to CONSPAN

Since f'_{ci} > 6 ksi, Initial Camber Deflection Multiplier = 0.95
Initial Camber = (0.95)*(3.884 in) = 3.690 in

Since Initial Camber > 1.5 in, Final Camber Deflection Multiplier = 1.60
Final Camber = (1.60)*(3.690 in) = 5.904 in