5.22 Prestressing Considerations For Cast-In-Place Prestressed Box Girders

5.22.1 GENERAL

This memo provides block-out dimensions and minimum diaphragm thicknesses related to post-tensioning anchorage systems. It also provides maximum tendon/duct curvature recommendations and guidance on determining the maximum cable path eccentricities for both straight and curved girders.

This memo is divided into three sections. Section 5.22.2 addresses post-tensioning block-out dimensions and minimum diaphragm thicknesses for both end and hinge diaphragms, considering varying levels of jacking force, skew, and whether the girder is straight or sloped. Section 5.22.3 addresses recommendations for tendon/duct curvature to minimize local prestress radial forces and to better facilitate tendon installation. Section 5.22.4 provides design guidance for locating tendon path vertices to maximize prestress efficiency for both straight and curved girders. Figure 5.22.1-1 illustrates these addressed locations for post-tensioning details.

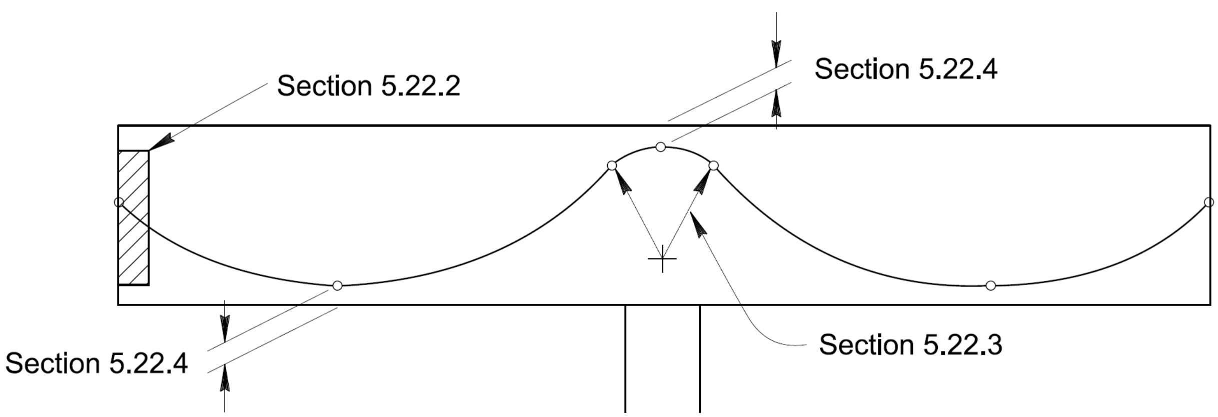


Figure 5.22.1-1 – Addressed Locations for Post-Tensioning Details

5.22.2 BLOCK-OUT DIMENSIONS AND MINIMUM DIAPHRAGM THICKNESS

During the stressing operation, space is needed to accommodate the placement of the jack. Block-outs are provided at the end and hinge diaphragms for this purpose, as well as to provide room to encase the grout cap with concrete after the stressing operation is complete. The designer must verify that there is enough structure depth available to accommodate the block-out. Table 5.22.2-1 provides minimum girder width recommendations and block-out dimensions as a function of the jacking force.

Table 5.22.2-1 Minimum Girder Width and Block-out Dimensions

Jacking Force (kips/girder)	Minimum Girder Width (inches)	Block-out Dimensions	
		Width (inches)	Height (inches)
0 to less than 1,200	12	27	27
1,200 to less than 2,400	12	27	48
2,400 to less than 3,600	12	27	69
3,600 to less than 4,800	12	27	90
4,800 to 6,000	12	27	111

Table 5.22.2-2 Minimum Diaphragm Thickness (Vertical Exterior Girders)

Skew Angle (degrees)	Minimum Diaphragm Thickness at Abutments	Minimum Diaphragm Thickness at Hinges
0 to less than 15	2’-6”	2’-0”
15 to less than 30	3’-3”	2’-9”
30 to less than 45	4’-0”	3’-6”
45 to 55	4’-9”	4’-3”

Note: Dimensions are normal to centerline of diaphragm.

Table 5.22.2-3 Minimum Diaphragm Thickness (Sloped Exterior Girders)

Skew Angle (degrees)	Minimum Diaphragm Thickness at Abutments		Minimum Diaphragm Thickness at Hinges	
	P_{jack} < 2400 kips	$P_{jack} \geq$ 2400 kips	P_{jack} < 2400 kips	$P_{jack} \geq$ 2400 kips
0 to less than 15	3’-0”	3’-3”	2’-8”	3’-0”
15 to less than 30	3’-4”	4’-3”	3’-4”	4’-0”
30 to less than 45	4’-0”	5’-0”	3’-8”	4’-8”
45 to 55	4’-4”	5’-6”	4’-0”	5’-3”

Notes: 1. P_{jack} is per girder.
2. Dimensions are normal to centerline of diaphragm.

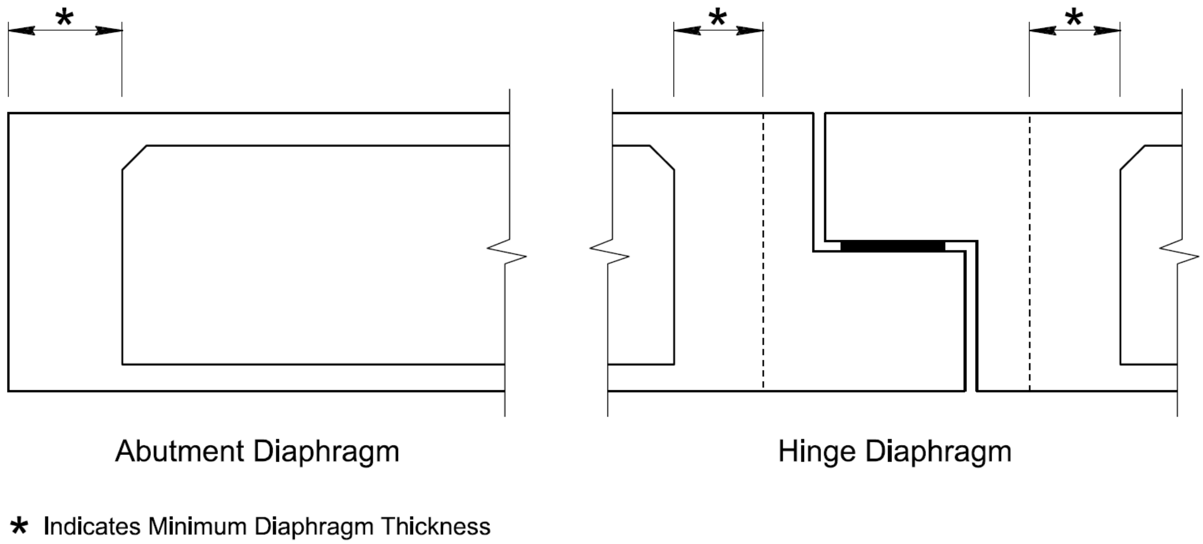


Figure 5.22.2-1 – Diaphragm Locations

The minimum diaphragm thicknesses shown in Tables 5.22.2-2 and 5.22.2-3 satisfy the Standard Plan B8-5 requirement of 1’-6” clearance between the prestress block-out and the interior face of diaphragm (see Figure 5.22.2-2). However, AASHTO LRFD General Zone design requirements and BDM 5.26.4.1 may influence or control the diaphragm thickness. When the skew angle is greater than 55 degrees, further study is needed for the diaphragm thickness. The additional thickness at sloped exterior girders is only necessary at exterior bays. Sloped exterior girders are assumed to be 1H:2V. For flatter exterior girder slopes, a special investigation for the diaphragm thickness should be made.

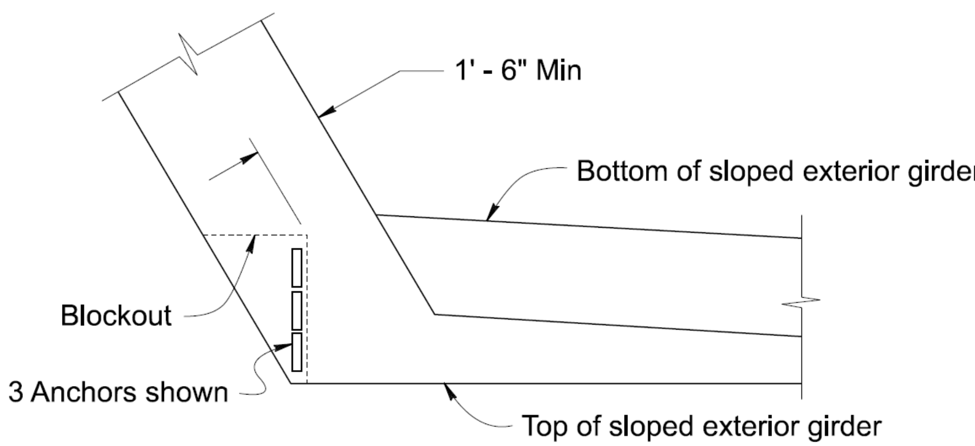


Figure 5.22.2-2 – Plan View of Skewed End Diaphragm with Sloped Exterior Girder

5.22.3 TENDON AND DUCT CURVATURE

The use of sharp curvatures for the tendon path in the vertical plane can result in large radial forces equal to the prestress force divided by the radius of the tendon. Refer to AASHTO-CA Articles 5.9.5.4.3, 5.9.5.4.4, and 5.9.5.4.5 for tendon and duct curvature requirements. Where tendons are in contact with one another, these forces can crush adjacent ducts. Sharp duct curvatures can also make tendon installation a challenge. Locating tendon inflection points at 10% of each span length away from the centerline of the bent in continuous frames ensures a smooth cable path with acceptable vertical curvature. Most CIP PS structures have relatively flat cable paths, with the exception of some post-tensioned bent caps.

5.22.4 MAXIMUM CABLE PATH ECCENTRICITIES

The cable path high and low points are illustrated in Figure 5.22.4-2 for typical girders. Figure 5.22.4-3 illustrates the cable path low point for a curved girder using “Detail A” from BDM 5.27, *Curved Cast-In-Place Prestressed Box Girders*. Figure 5.22.4-4 provides a quick and accurate method for determining “*D*”. Use the recommended “*D*” values based on an initial estimate of P_{jack} per girder to define the initial cable path. Revise “*D*” based on P_{jack} obtained from the initial analysis. Refine the analysis further by using the revised “*D*” value until convergence is reached and the cable path is optimized. Refer to Standard Plan B8-5 and BDM 5.27 for conditions that warrant the use of “Detail A”.

When designing railroad bridges, the American Railway Engineering and Maintenance-of-Way Association and individual railroad company requirements must be met.

Strands within a tendon shift to the top of the duct at midspan and remain at the bottom of the duct over the bent cap. The value of the tendon offset within the duct is defined as “*Z*” and is included in the development of the “*D*” chart. Figure 5.22.4-1 illustrates the development of the “*Z*” value.

Duct Size	"Z" Value
3" OD and less	½"
Over 3" OD to 4"	¾"
Over 4" OD	1"

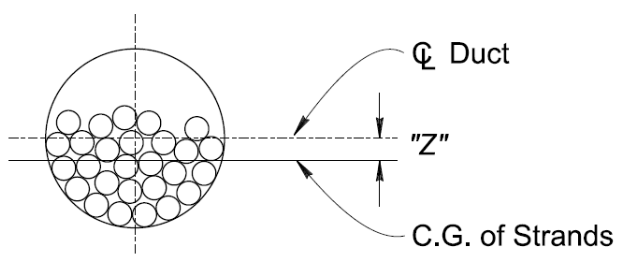
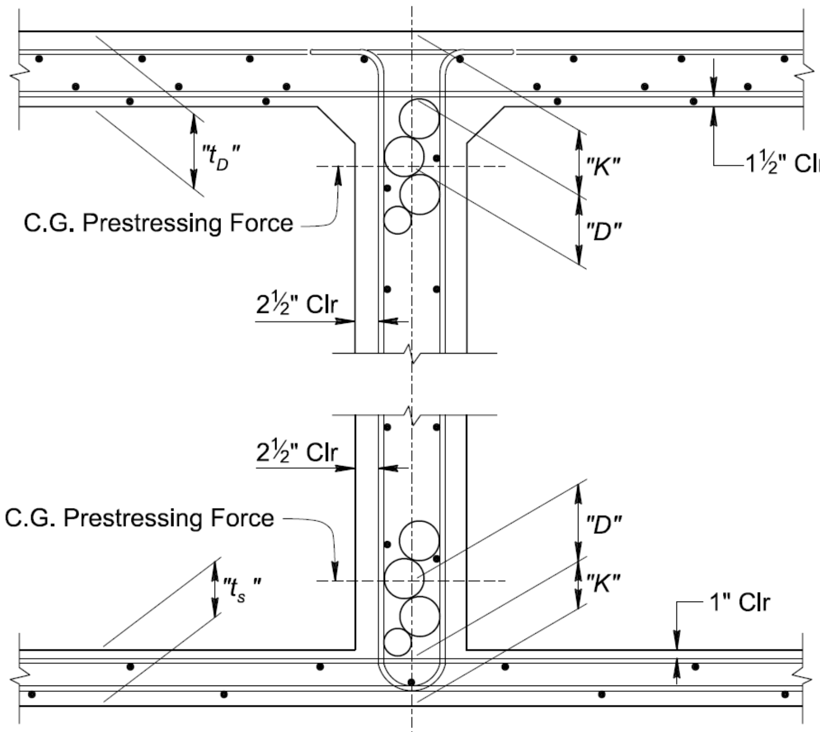


Figure 5.22.4-1 – “*Z*” Value as a Function of Duct Diameter



"*K*" – Values calculated from the top of the deck to the bottom of the transverse deck reinforcement or bent cap reinforcement (particularly when the skew angle of the bent cap exceeds 20 degrees) or from the bottom of the soffit to the top of the transverse soffit reinforcement.

"*D*" – Refer to Figure 5.22.4-4

"t_D" – deck thickness

"t_s" – Soffit thickness

Figure 5.22.4-2 – Typical Prestress Duct Configuration

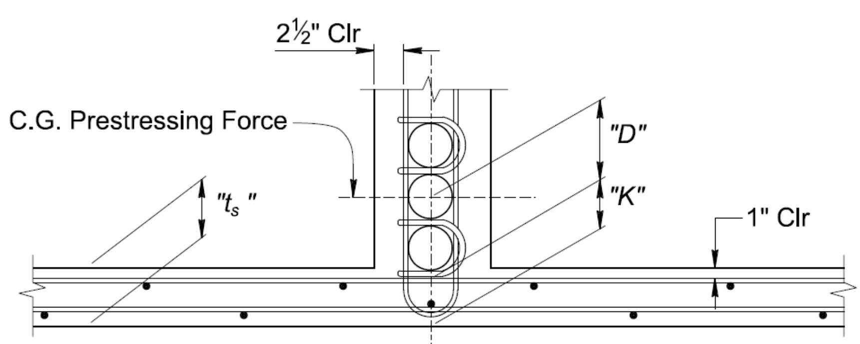


Figure 5.22.4-3 – Prestress Duct Configuration for Curved Girder with "Detail A"

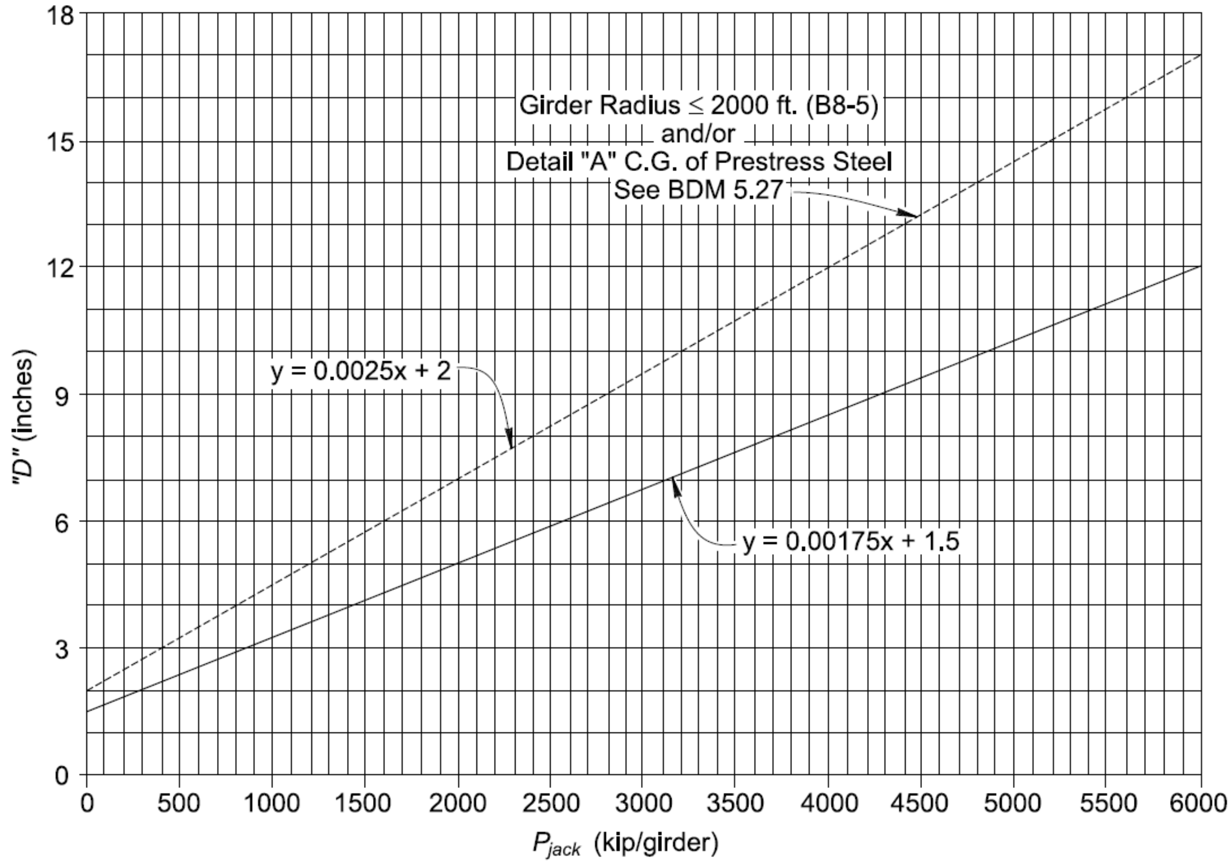


Figure 5.22.4-4 – "*D*" Chart for Cast-in-Place Prestressed Box Girders

Other assumptions considered in the development of Figures 5.22.4-2, 5.22.4-3 and 5.22.4-4 are as follows:

1. Girders have a width of 12 inches.
2. Figure 5.22.4-4 was developed empirically considering a variety of different jacking forces in combination with a varying number of girders.
3. Sloped exterior girders are accounted for in Figure 5.22.4-4.
4. Duct configurations conform to *Standard Plans* B8-5.
5. When required for curved post-tensioned girders, duct configurations conform to the clearance recommendations included in BDM 5.27, *Curved Cast-In-Place Prestressed Box Girders*.
6. There is 2-½ inches of clearance between the stirrup and the face of the girder.

5.22.5 REFERENCES

1. AASHTO. (2017). *AASHTO LRFD Bridge Design Specifications*, 8th Edition, American Association of State Highway and Transportation Officials, Washington, DC.
2. Caltrans. (2024). *Standard Plans* B8-5, California Department of Transportation, Sacramento, CA.
3. Caltrans. (2021). Bridge Design Memo 5.26, *Anchorage Zone for Cast-In-Place Prestressed Box Girders*, California Department of Transportation, Sacramento, CA
4. Caltrans. (2021). Bridge Design Memo 5.27, *Curved Cast-In-Place Prestressed Box Girders*, California Department of Transportation, Sacramento, CA.
5. Caltrans. (2019). *California Amendments to AASHTO LRFD Bridge Design Specifications*, *8th Edition*, California Department of Transportation, Sacramento, CA.