ATTACHMENT 1

11-1 CHECKING PRESTRESS SHOP DRAWINGS

Example

Consider a two-span CIP/PS box girder bridge with skewed supports and horizontal curvature.

Details from Contract Plans:

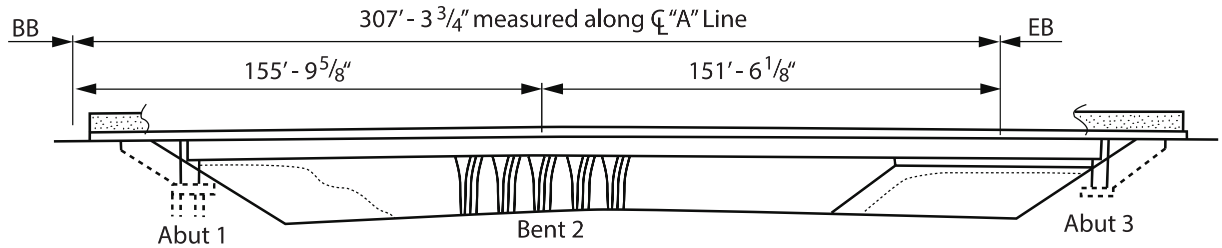


Figure 1 - Elevation

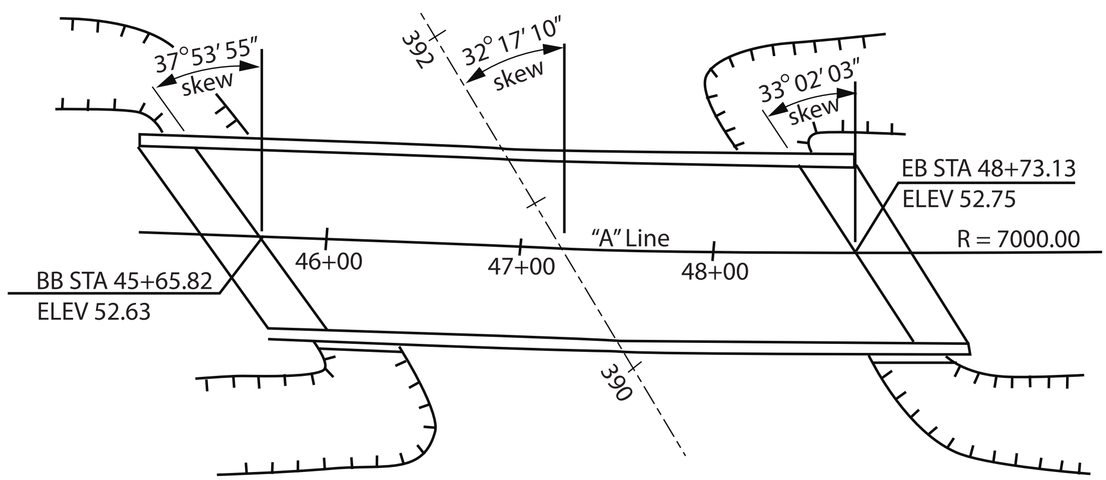


Figure 2 - Plan View

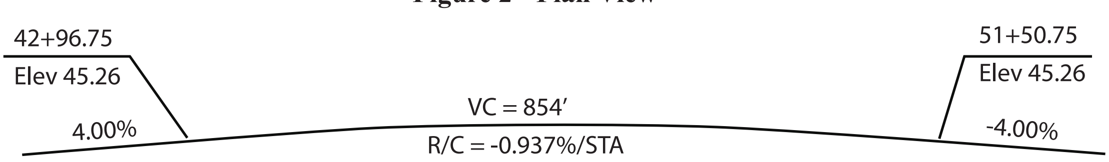


Figure 3 - Bridge Profile Grade

ATTACHMENT 1

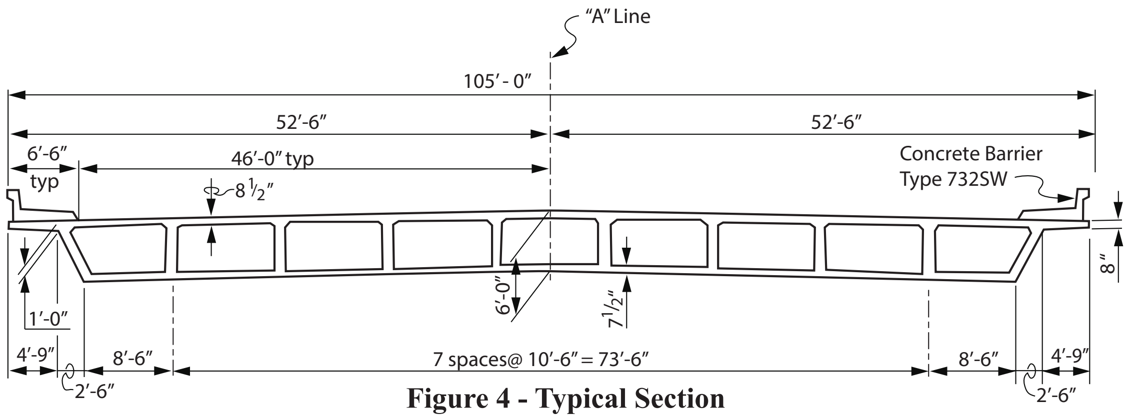


Figure 4 - Typical Section

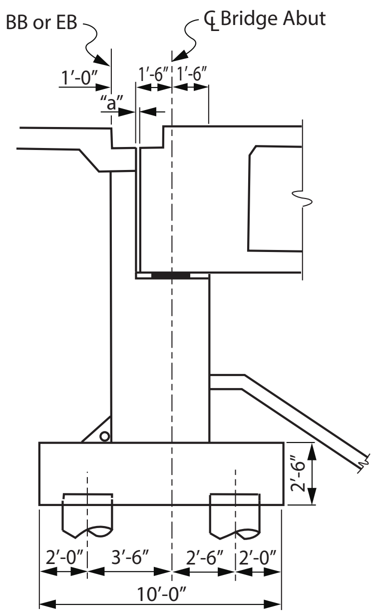


Figure 5 - Abutment Section

PRESTRESSING NOTES

270 KSI Low Relaxation Strand:

P_{jack}	=	29,100	kips
Anchor Set	=	$^{3}/_{8}$	in
Friction curvature coefficient, μ	=	0.15	(1/rad)
Friction wobble coefficient, κ	=	0.0002	(1/ft)
Assumed long term losses	=	20	(ksi)
Total Number of Girders	=	10	

The final force ratio (larger divided by smaller) between any two girders shall not exceed the ratio of 10 to 9

Concrete: f'_c = 5000 psi @ 28 days

f'_{ci} = 3600 psi @ time of stressing

Contractor shall submit elongation calculations based on initial stress at

□ = 0.877 times jacking stress.

One end stressing shall be performed from Abutment 1 only

Figure 6 - Prestressing Notes

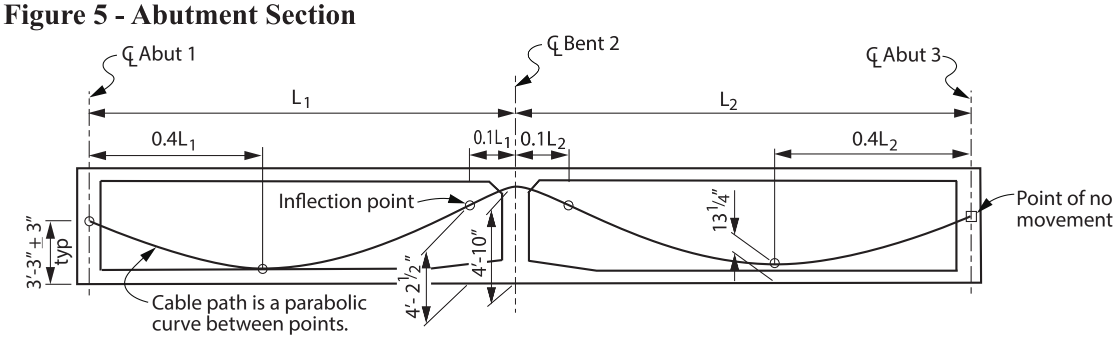
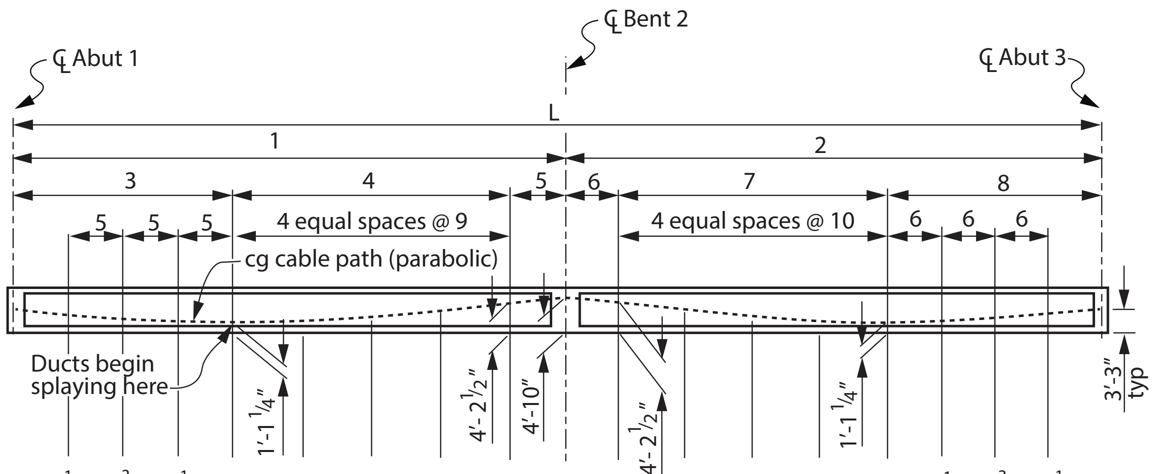


Figure 7 - Longitudinal Section

Prestress Shop Drawing Information:



Webs B-I	top	38 1/2"	25 3/8"	17 1/2"	-	-	-	-	-	-	-	-	-	-	-	17 1/2"	25 3/8"	38 1/2"
	middle	25 1/2"	17 1/4"	12 3/8"	-	-	-	-	-	-	-	-	-	-	-	12 3/8"	17 1/4"	25 1/2"
	bottom	12 1/4"	9 1/8"	7 1/8"	6 1/2"	8 7/8"	15 7/8"	27 3/4"	44 1/4"	52 3/8"	44 1/4"	27 3/4"	15 7/8"	8 7/8"	6 1/2"	7 1/8"	9 1/8"	12 1/4"
Webs A&J	top	38 1/8"	24 3/4"	16 3/4"	-	-	-	-	-	-	-	-	-	-	-	16 3/4"	24 3/4"	38 1/8"
	middle	25 1/4"	16 7/8"	11 7/8"	-	-	-	-	-	-	-	-	-	-	-	11 7/8"	16 7/8"	25 1/4"
	bottom	12 3/8"	9 1/8"	7 1/8"	6 1/2"	8 7/8"	15 7/8"	27 3/4"	44 1/4"	52 3/8"	44 1/4"	27 3/4"	15 7/8"	8 7/8"	6 1/2"	7 1/8"	9 1/8"	12 3/8"

Distance from soffit to bottom of bottom duct, typ

Figure 8 - Duct Profile

Attachment 1

Table 1 Duct Geometry

WEB	L	1	2	3	4	5	6	7	8	9	10
A	307.55	159.67	147.88	63.86	79.83	15.97	14.79	73.94	59.16	19.96	18.49
B	306.74	158.49	148.25	63.40	79.25	15.85	14.82	74.13	59.30	19.81	18.53
C	305.85	157.18	148.67	62.88	78.59	15.72	14.86	74.33	59.47	19.65	18.58
D	304.95	155.86	149.09	62.34	77.93	15.58	14.91	74.54	59.64	19.48	18.64
E	304.07	154.56	149.51	61.82	77.28	15.46	14.95	74.75	59.80	19.32	18.69
F	303.19	153.25	149.94	61.30	76.63	15.32	14.99	74.97	59.98	19.16	18.74
G	302.31	151.96	150.35	60.78	75.98	15.20	15.03	75.18	60.14	19.00	18.79
H	301.42	150.65	150.77	60.26	75.32	15.06	15.07	75.39	60.31	18.83	18.84
I	300.56	149.35	151.21	59.74	74.68	14.94	15.13	75.60	60.48	18.67	18.91
J	299.77	148.21	151.56	59.28	74.10	14.82	15.16	75.78	60.63	18.53	18.95

All lengths are in feet.

Check Calculations

STEP 1: Compare the control points along the cable path c.g. (Fig. 8) with the structure plans (Fig. 7).

The vertical dimensions to compare in this example are: 3′-3″, 1′-1¼″, 4′-2 ½″, and 4′-10″. These values must compare exactly, and in this case they do. Be sure to highlight each checked item on the shop plans file copy as you proceed. (Fig. 9)

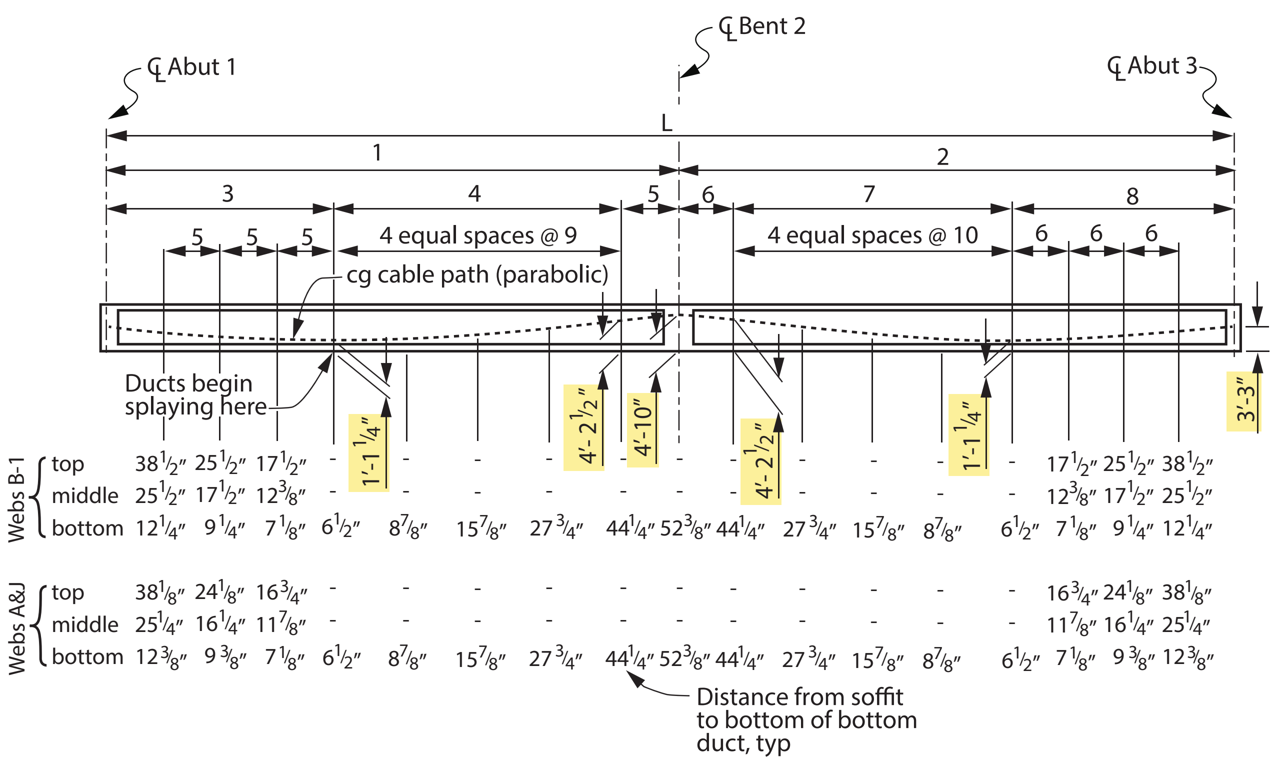


Figure 9 - Control Points Checked

STEP 2: Check the provided lengths in Table 1.

This example is an extreme case as each girder has a different length due to the varying skew and the horizontal curvature. The best way to check girder lengths, in this case, is graphically. For exterior girders which are sloped, use the midpoint of the girder height and thickness to determine its length. For this example, assume the above values in Table 1 have been checked and are all accurate. Always highlight values which have been checked and are correct. The tolerance is ½″. Spacing between cable path bottom of duct points should not exceed 20 feet (see columns 5, 6, 9, and 10). The current CT specifications require duct points at least every $^{1}/_{8}{}^{th}$ point of the span.

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STEP 3: Calculate the average c.g.s. (center of gravity of strands) relative to the bottom of the lowest duct at the low point, inflection point, and high point.

Start by calculating the center to center vertical distance between ducts including the effect of duct stack stagger and accounting for side face reinforcement.

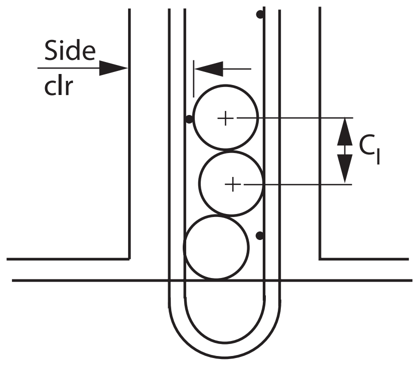

Figure 10 – Typical Interior Girder

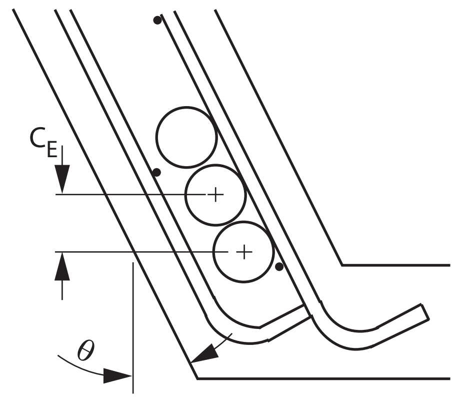

Figure 11 – Typical Exterior Girder

Table 2 Provided Tendon Sizes (Shop Plans)

TENDON SIZE	DUCT I.D.	DUCT O.D.	"Z" VALUE
22x0.6"	4.0"	4.20"	0.50"
24x0.6"	4.25"	4.45"	0.71"

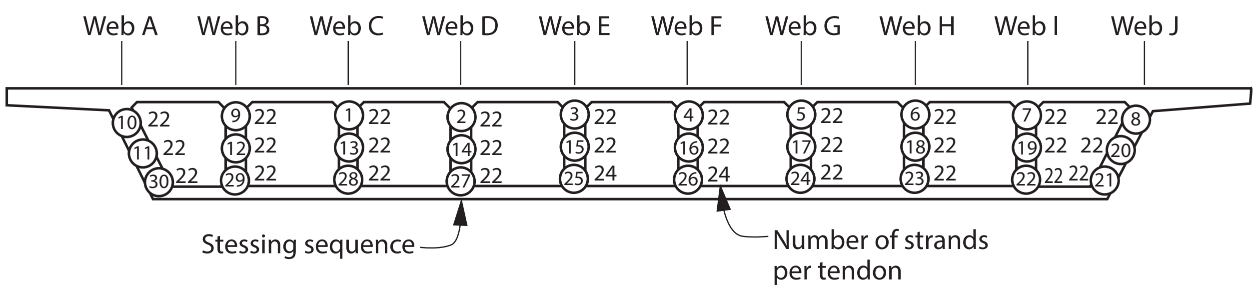

Figure 12 - Stressing Sequence (Shop Plan Drawing)

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Center to Center vertical distance between 22 strand ducts in Webs A and J:

$$C_E = \left(\frac{4.2}{2} + \frac{4.2}{2}\right) \times \cos 26.5° = 3.76\ in$$

Center to Center vertical distance between 22 strand ducts in Webs B-I:

$$\textit{Clear gap between stirrup legs and ducts} = 12'' - 2.5'' \times 2 - \frac{4.2}{2} - \frac{4.2}{2} - 0.88 \times 2 - 0.56 = 0.48\text{in}$$

This assumes #6 stirrups and a single #4 side face bar affecting the allowable clear space. The standard plans allow 2.5” to 4” clearance. 2.5” clearance was used to maximize duct stack.

$$C_I = \sqrt{\left(\frac{4.2}{2} + \frac{4.2}{2}\right)^2 - 0.48^2} = 4.17in$$

Center to Center vertical distance between 22 and 24 strand ducts in Webs E and F:

$$\textit{Clear gap between stirrup legs and ducts} = 12'' - 2.5'' \times 2 - \frac{4.2}{2} + \frac{4.45}{2} - 0.88 \times 2 - 0.56 = 0.36in$$

$$C_I = \sqrt{\left(\frac{4.2}{2} + \frac{4.45}{2}\right)^2 - 0.36^2} = 4.31in$$

Average c.g.s. from bottom duct LOL:

cg@ low point = $(2[22(^{4.2}/_2 + 0.5) + 22\,(^{4.2}/_2 + 3.76 + 0.5) + 22\,(^{4.2}/_2 + 3.76 + 3.76 + 0.5)] + 6[22(^{4.2}/_2 + 0.5) + 22\,(^{4.2}/_2 + 4.17 + 0.5) + 22\,(^{4.2}/_2 + 4.17 \times 2 + 0.5)] + 2[24\,(^{4.45}/_2 + 0.71) + 22(^{4.45}/_2 + 4.31 + 0.5) + (^{4.45}/_2 + 4.31 + 4.17 + 0.5)])/(664\ \textit{strands}) = 6.72\ in$

cg@ inflection point = $(2[22(^{4.2}/_2) + 22\,(^{4.2}/_2 + 3.76) + 22\,(^{4.2}/_2 + 3.76 + 3.76)] + 6[22\,(^{4.2}/_2) + 22(^{4.2}/_2 + 4.17) + 22\,(^{4.2}/_2 + 4.17 \times 2) + 2[24\,(^{4.45}/_2) + 22\,(^{4.45}/_2 + 4.31) + 22(^{4.45}/_2 + 4.31 + 4.17)])/(664\ \textit{strands}) = 6.21\ in$

cg@ high point = $(2[22(^{4.2}/_2 - 0.5) + 22\,(^{4.2}/_2 + 3.76 - 0.5) + 22\,(^{4.2}/_2 + 3.76 + 3.76 - 0.5)] + 6[22(^{4.2}/_2 - 0.5) + 22\,(^{4.2}/_2 + 4.17 - 0.5) + 22\,(^{4.2}/_2 + 4.17 \times 2 - 0.5)] + 2[24\,(^{4.45}/_2 - 0.71) + 22(^{4.45}/_2 + 4.31 - 0.5) - 22\,(^{4.45}/_2 + 4.31 + 4.17 - 0.5)])/(664\ \textit{strands}) = 5.69\ in$

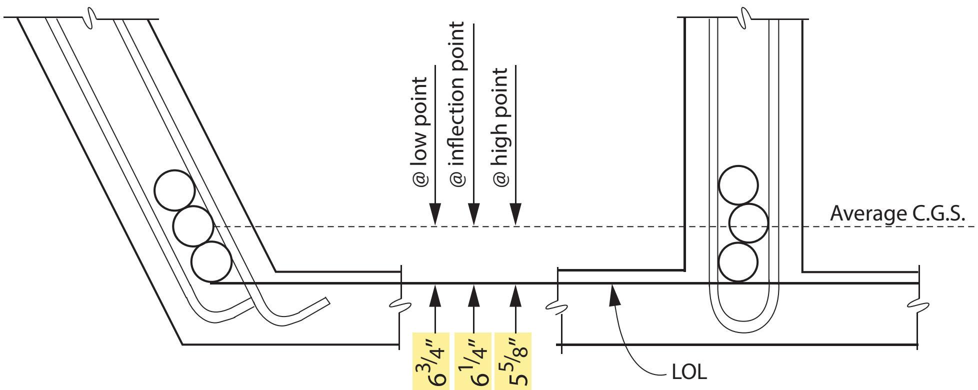

Figure 13 - Average C.G. from LOL Checked (Shop Plan Drawing)

STEP 4: Check the cable path layout (bottom of duct)

The layout is provided in Figure 8 which represents the shop plan duct profile as provided to the Engineer. The c.g.s. of each control point was already checked in step 1. Now check the LOL for each of these control points (use calculated values). The tolerance is ¼″.

Span 1 low point: 13.25″ – 6.72″ = 6.53″	6.50″ provided, OK
Span 1 inflection point: 50.5″ – 6.21″ = 44.29″	44.25″ provided, OK
Bent 2 high point: 58″ – 5.69″ = 52.31″	52.38″ provided, OK
Span 2 locations are the same by symmetry.	

Next, check the c.g.s. at the anchorage areas. The goal here is to make sure the anchorage layout on the shop drawings (Figure 14) matches the Figure 8 dimensions.

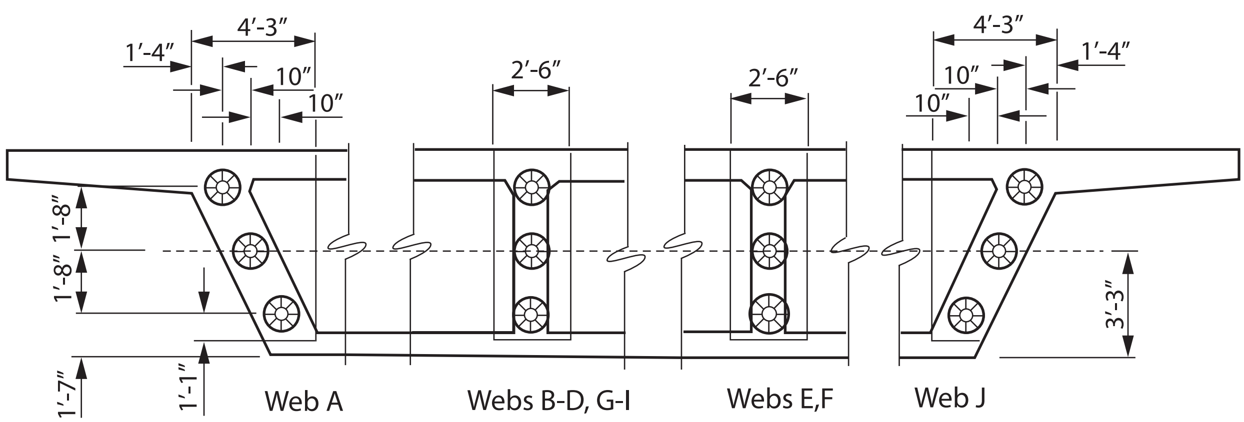

Figure 14 - Anchorage Area PT Duct Layout (Shop Plan Drawing)

ATTACHMENT 1

$$\text{Anchorage Area cg} = \frac{[19(22\times8+24\times2)+39(22\times10)+59(22\times10)]}{664} = 38.88''$$

Figure 8 anchorage location = 3′-3″ (39″). The anchorage layout is OK.

Next check the vertical profile layout at each intermediate point between the control points. This will require creating an equation of a parabola for each segment between control points. Herein will be shown the solution for the parabolas in span 1. The other locations are calculated in a similar manner.

Use the vertex form of a parabola equation: $y = a(x-h)^2+k$

The vertex is the low point on this parabola with coordinates (h, k). To determine a, insert the coordinates for either the first point or last point on the parabola. In the first segment, the ducts are splayed, therefore a parabola is needed for each of the 3 tendons and layout line offsets, relative to the bridge soffit, and must be provided for each tendon at the intermediate points. Ducts must begin splaying from the low point to the anchorage.
In this example, Web E geometry is used. Figure 15 shows the profile of the c.g.s. along with the bottom of each tendon. The labeled points indicate intermediate points provided on the shop drawings which require checking.

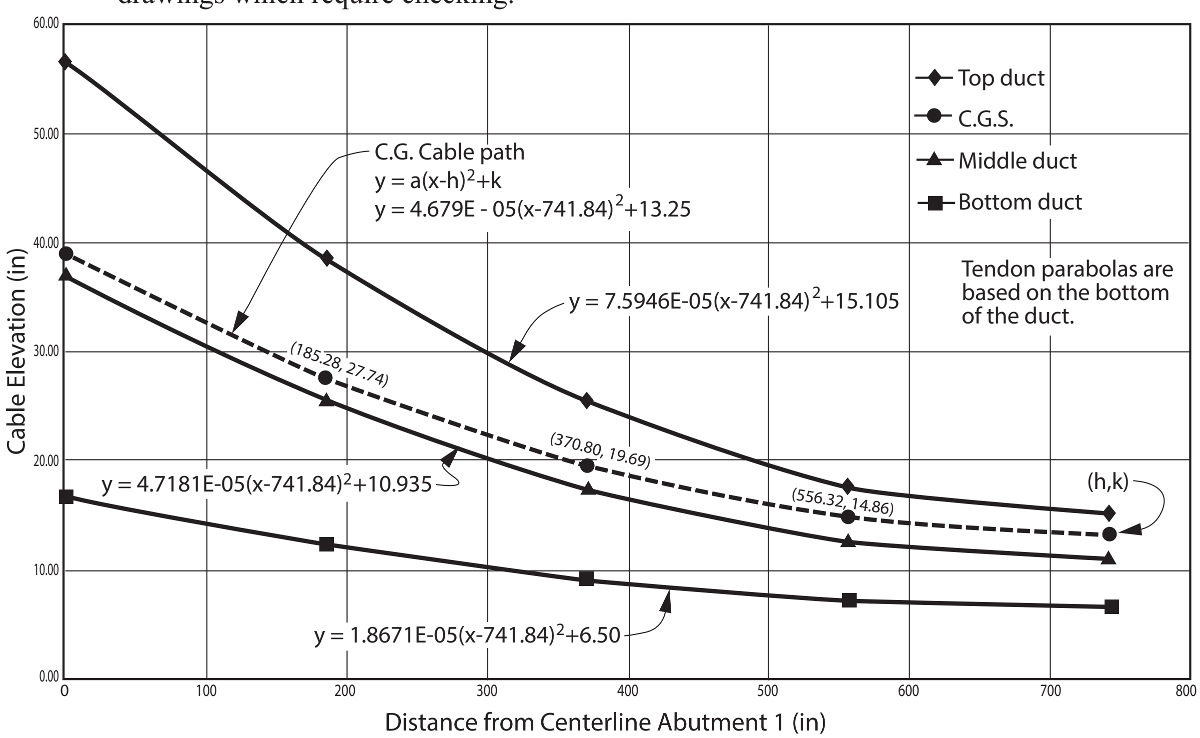

Figure 15 - Cable Path Parabolas at Web E

ATTACHMENT 1

To check the shop drawing value for each tendon, create parabolas for each tendon using the known end points. The first intermediate point is at location x = 185.28. For the bottom duct the vertical profile at this location is:

$$y = 0.000018671*(185.28-741.84)^2+6.50 = 12.28in$$

The shop drawing value is 12 $^1/_4$″. Value checks out OK.

The second intermediate point is at location x = 370.80. Checking the 2nd intermediate point for the bottom duct:

$$y = 0.000018671*(370.80-741.84)^2+6.50 = 9.07in$$

The shop drawing value is 9 $^1/_8$″. Value checks out OK.

The third intermediate point is at location x = 556.32. Checking the 3rd intermediate point for the bottom duct:

$$y = 0.000018671*(556.32-741.84)^2+6.50 = 7.14in$$

The shop drawing value is 7 $^1/_8$″. Value checks out OK.

Next, let's check the intermediate points for the parabola between the span 1 low point and the inflection point. Since the ducts are stacked for this segment, only the bottom duct parabola needs to be calculated. With the y-axis located at the low point for web E, this parabolic equation is:

$$y = 0.000043895x^2+6.5$$

At the 1st intermediate point the offset to the bottom duct is:

$$y = 0.000043895(231.84)^2+6.5=8.86\text{in}$$

Shop plan value is 8$^7/_8$″, value checks out OK.

The 2nd and 3rd intermediate points for this segment are checked in a similar way.

Since there are no intermediate points to check between the points of inflection and the high point, there are a total of 16 parabolas to check on this bridge.

At the end of this document, an alternate method is shown to check the vertical profile using only the LOL offsets, without using parabolas. This method may not be applicable to all shop drawings.

ATTACHMENT 1

STEP 5: Check prestressing calculations (P_{JACK})

The total number of strands: $No.strands = \dfrac{P_j}{0.75 f_u A_s}$

$$\text{No. of } 0.6\text{''}\ \phi\ strands = \frac{29{,}100\,kips}{0.75 * 270\,ksi * 0.217\,in^2} = 662.2$$

The shop plans indicate 664 strands are used. Therefore, the number of strands is OK.

Additionally, check to make sure the chosen number of strands and tendons adds up to the required total. For this check, use the stressing sequence drawing (Figure 12).

No.strands =28*22+2*24=664 strands OK
Force per strand = 29,100/664=43.825k
Pj for 22 strand tendon=22*43.825=964k
Pj for 24 strand tendon=24*43.825=1052k

STEP 6: Check temporary force variation

There are 3 requirements in the standard specifications (Section 50) regarding sequencing of the prestressing operation:

1. No more than 1/6 of the prestressing force can be applied eccentrically about the centerline of the structure.
2. Prior to applying more than ½ of the prestressing force in a girder, at least an equal force must have already been applied in the adjacent girders.
3. The maximum force variation between girders must not exceed the force of the largest tendon used in all of the girders.

Checking item 1) can be accomplished with a simple table that accumulates the eccentric force through each sequence as shown in Table 3 below. Arbitrarily, prestressing forces on the left side of the centerline of structure are called positive and forces on the right side are negative.

Attachment 1

Table 3 Sequencing Check for Eccentric Force about Centerline

Unbalance cannot exceed 1/6 of total P_{jack} =				4850 k	
				Cumulative	
Sequence #	w eb	# strands	force	unbalance	< 4850 k ?
1	C	22	964 k	964 k	OK
2	D	22	964 k	1928 k	OK
3	E	22	964 k	2892 k	OK
4	F	22	-964 k	1928 k	OK
5	G	22	-964 k	964 k	OK
6	H	22	-964 k	0 k	OK
7	I	22	-964 k	-964 k	OK
8	J	22	-964 k	-1928 k	OK
9	B	22	964 k	-964 k	OK
10	A	22	964 k	0 k	OK
11	A	22	964 k	964 k	OK
12	B	22	964 k	1928 k	OK
13	C	22	964 k	2892 k	OK
14	D	22	964 k	3857 k	OK
15	E	22	964 k	4821 k	OK
16	F	22	-964 k	3857 k	OK
17	G	22	-964 k	2892 k	OK
18	H	22	-964 k	1928 k	OK
19	I	22	-964 k	964 k	OK
20	J	22	-964 k	0 k	OK
21	J	22	-964 k	-964 k	OK
22	I	22	-964 k	-1928 k	OK
23	H	22	-964 k	-2892 k	OK
24	G	22	-964 k	-3857 k	OK
25	E	24	1052 k	-2805 k	OK
26	F	24	-1052 k	-3857 k	OK
27	D	22	964 k	-2892 k	OK
28	C	22	964 k	-1928 k	OK
29	B	22	964 k	-964 k	OK
30	A	22	964 k	0 k	OK

In order to check the ½ rule (item 2 above), one can do so by inspection or again create a spreadsheet or table to track the sequence. Refer to Table 4 below.

Table 4 Sequencing Check ($^1/_2$ rule)

Sequence #	web	# strands	A added force this sequence	B cumulative force in web	1/2 web total force	More than 1/2 applied?	C Min adjacent web force	C≥B-A ? OK?
1	C	22	964 k	964 k	1446	NO	0	OK
2	D	22	964 k	964 k	1446	NO	0	OK
3	E	22	964 k	964 k	1490	NO	0	OK
4	F	22	964 k	964 k	1490	NO	0	OK
5	G	22	964 k	964 k	1446	NO	0	OK
6	H	22	964 k	964 k	1446	NO	0	OK
7	I	22	964 k	964 k	1446	NO	0	OK
8	J	22	964 k	964 k	1446	NO	0	OK
9	B	22	964 k	964 k	1446	NO	0	OK
10	A	22	964 k	964 k	1446	NO	0	OK
11	A	22	964 k	1928 k	1446	YES	964	OK
12	B	22	964 k	1928 k	1446	YES	964	OK
13	C	22	964 k	1928 k	1446	YES	964	OK
14	D	22	964 k	1928 k	1446	YES	964	OK
15	E	22	964 k	1928 k	1490	YES	964	OK
16	F	22	964 k	1928 k	1490	YES	964	OK
17	G	22	964 k	1928 k	1446	YES	964	OK
18	H	22	964 k	1928 k	1446	YES	964	OK
19	I	22	964 k	1928 k	1446	YES	964	OK
20	J	22	964 k	1928 k	1446	YES	1928	OK
21	J	22	964 k	2892 k	1446	YES	1928	OK
22	I	22	964 k	2892 k	1446	YES	1928	OK
23	H	22	964 k	2892 k	1446	YES	1928	OK
24	G	22	964 k	2892 k	1446	YES	1928	OK
25	E	24	1052 k	2980 k	1490	YES	1928	OK
26	F	24	1052 k	2980 k	1490	YES	2892	OK
27	D	22	964 k	2892 k	1446	YES	2980	OK
28	C	22	964 k	2892 k	1446	YES	2980	OK
29	B	22	964 k	2892 k	1446	YES	2980	OK
30	A	22	964 k	2892 k	1446	YES	2980	OK

Finally, the check of item 3) for temporary force variation can be done by inspection. Looking at Figure 12, the maximum number of strands is 24 in webs E and F. So long as any one girder does not have more than a 24 strand difference from any other girder during any given sequence, this criteria is met. By inspection, the maximum variation occurs after sequence 25. At this moment in time, girder E will have a 24 strand difference from girders A-D and F. This is the maximum difference allowed so it is OK.

STEP 7: Check the final force variation

In Figure 6 above, the prestressing notes indicate to the contractor the allowable final force variation. For this example, the variation that is permitted is 10:9.

This check is easily made by making a table to compare final forces between girders. See Table 5. Additionally, verify the final force is symmetrical about the centerline of structure.

Table 5 Final Force Variation

Girder	# strands	force
A	66	2892 k
B	66	2892 k
C	66	2892 k
D	66	2892 k
E	68	2980 k
F	68	2980 k
G	66	2892 k
H	66	2892 k
I	66	2892 k
J	66	2892 k
	Minimum =	2892 k
	Maximum =	2980 k
	Ratio =	1.03 OK, less than 1.11

STEP 8: Check the Prestressing Calculations (Elongations)

One-end stressing elongation formula: $\Delta = \dfrac{T_o(1+\otimes)(L+2.5')}{2E_s}$

$$T_o = \frac{29100}{0.217 * 664} = 201.96\ ksi$$

$$\otimes = 0.877$$

$$L = \textit{varies (see table 1)}$$

$$E_s = 28{,}500\ ksi$$

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$$\textit{Web A Elongation: } \Delta = \frac{201.96(1+0.877)(307.55+2.5)*12}{2*28,500} = 24.74''$$

2.5ft is added to *L* to account for the length of strand in the hydraulic jack.

Table 6 Elongation Calculations

Location	L(ft)	Δ (in)	80%Δ (in)
Web A	307.55	24.74	19.80
Web B	306.74	24.68	19.74
Web C	305.85	24.61	19.69
Web D	304.95	24.54	19.63
Web E	304.07	24.47	19.57
Web F	303.19	24.40	19.52
Web G	302.31	24.33	19.46
Web H	301.42	24.25	19.40
Web I	300.56	24.19	19.35
Web J	299.77	24.12	19.30

Length *"L"* is the projected length which is adequate for elongation calculations. E_s should be based on mill certifications, but if unavailable when checking shop drawings, adjustment is made later by field personnel. The above values in the table should compare to the shop drawing values with a tolerance of ½".

STEP 9: Check the Bearing Plate Vertical Slope

On the shop plans, the following figure is provided to indicate the required bearing plate slope angle.

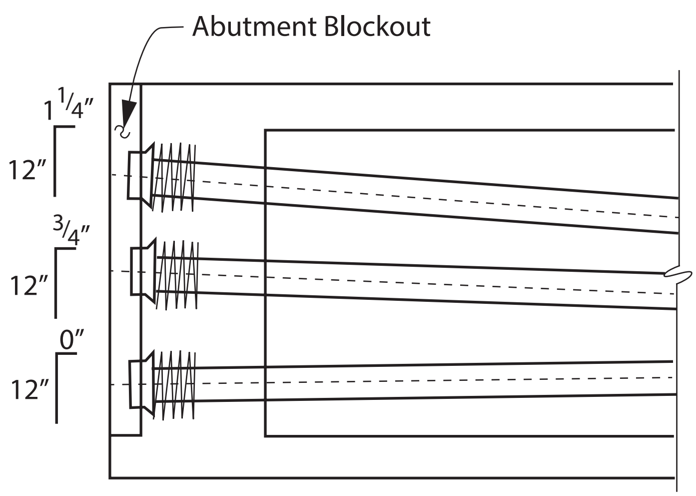

Figure 16 - Bearing Plate Angle

Attachment 1

The bearing plates need to be cast perpendicular to the tendon. To verify this, the slope of the tendon itself at the anchorage and the slope of the bridge at that location must be calculated. This verification can be accomplished graphically (by drawing to scale) or mathematically as shown below.

$$\textit{Slope of parabola: } \frac{dy}{dx} = 2a(x-h)$$

Since the tendons splay out at the anchorage, it is necessary to use a parabola for each tendon in order to determine the tendon slope. For the bottom tendon in Web E, the equation of the parabola along the bottom of duct is:

$$y = 1.867\text{E-}05\,(x-741.84)^2 + 6.50$$

$$\frac{dy}{dx}(\text{at } x = 0) = 2 * 1.867\text{E - }05\,(0-741.84) = -0.0277$$

The BB station is 45+65.82. Therefore, the bridge slope at abutment 1 is (refer to Fig.3):

$$\textit{bridge slope} = (45.6582 - 42.9675)*(^{-0.937\,\%}/_{\text{STA}}) + 4.00 = 1.479\%$$

Expressing this slope in decimal form: 0.01479.

The net slope of the bottom duct is therefore: (-0.0277+0.01479) = -0.0129.

The shop plans indicate 0. The percentage difference is 1.29% < 2.0%, this checks OK.

Theoretical tolerance is 2% or about ¼” in 12”. Standard Plan B8-5, Detail 5-2 indicates 2° difference is acceptable for field tolerance.

Next, check the slope of the middle duct. The parabolic equation for this tendon is:

$$y = 4.718\text{E-}05\,(x - 741.84)^2 + 10.935$$

$$\frac{dy}{dx}(at\ x = 0) = 2*4.718\text{E-}05\,(0-741.84) = -0.0700$$

$$\textit{Net slope} = -0.0700+0.01479 = -0.0552$$

The shop plans indicate -0.75″/12″ = -0.0625. The percentage difference is (0.0625-0.0552)*100 = 0.73% < 2.0%. This checks OK.

Finally, check the slope of the top duct. The parabolic equation for the top tendon is:

$$y = 7.594\text{E-}05\,(x-741.84)^2 + 15.105$$

$$\frac{dy}{dx}(at\ x = 0) = 2*7.594\text{E-}05\,(0-741.84) = -0.113$$

$$\textit{Net slope} = -0.113+0.01479 = -0.0982$$

The shop plans indicate -1.25″/12″ = -0.1042. The percentage difference is (0.1042-0.0982)*100 = 0.6% < 2.0%. This checks OK.

In general, these slopes can be calculated for each tendon of each girder. On this bridge, the BB station is an average only. The station of each girder is different due to the skew. Additionally, the individual tendon slope varies slightly due to the differing parabola lengths owing to the horizontal bridge curvature as well as skew. However, these differences do not result in appreciable differences in bearing plate slope for this bridge. Therefore, using a single set of values for all girders at each abutment is adequate.

These same calculations are performed at Abutment 3 as well. Note the tendon slopes will be positive at Abutment 3. However, the bridge slope is now negative. For brevity these calculations are not shown here.

STEP 10: Check the Bearing Plate Horizontal Slope and Blockout Depths

The blockout depths shown on the shop drawings will be affected by the bridge skew and the requirements in B8-5. The bearing plate slope is dependent on the horizontal curvature of the tendon. The goal is to ensure the bearing plate is cast in concrete perpendicular to the tendon, similar to the slope calculations done in Step 9.

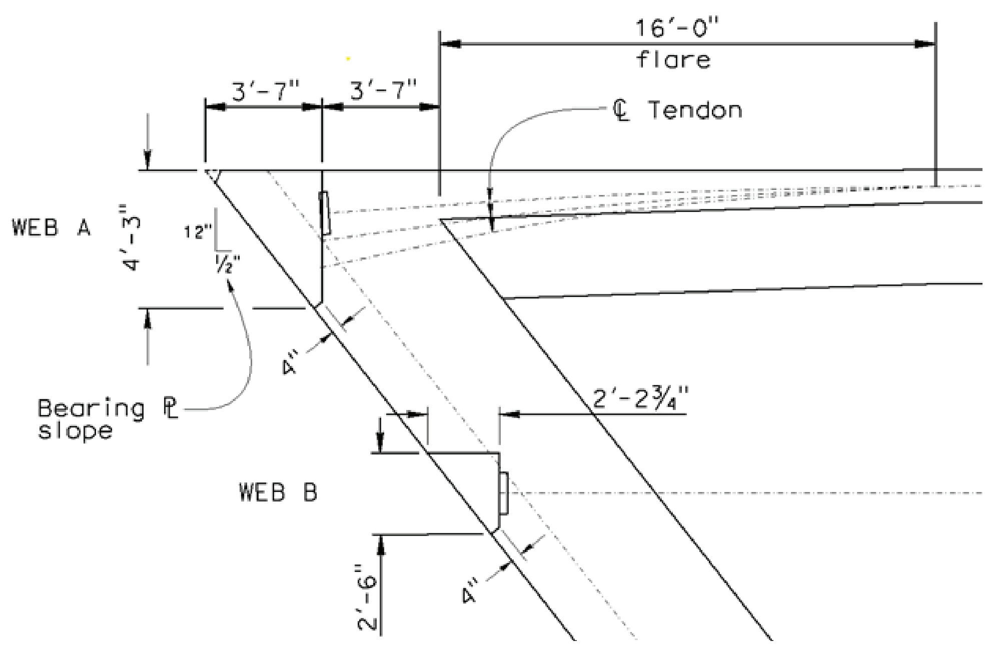

Figure 17 - Plan View Blockout Dimensions (Shop Plan Drawing)

ATTACHMENT 1

In Figure 17, dimensions are provided on the shop drawings indicating the depth of the blockout as well as the horizontal slope of the bearing plate, if any. For Web A, a horizontal slope is necessary (relative to the plane of the blockout) because at exterior girders the path needs to curve inward to allow enough room for the anchorage hardware and edge distance.

The dimensions 2′-6″ and 4′-3″ are provided by the contractor and are dependent on their system being used. Check the blockout depth based on these numbers.

WEB A: *Blockout Depth* = (4.25 + 0.333) * tan (37.898) = 3.57ft
3′-7″ was provided, OK.

WEB B: *Blockout Depth* =(2.5+0.333) * tan (37.898) = 2.21ft
2′-2 ¾″ was provided, OK.

Exterior girder bearing plate angle:

$$\tan^{-1}\left(\frac{1.333\,ft - 0.5\,ft}{19.58\,ft}\right) = 2.44°$$

(Refer to Figure 14 for horizontal offset)
Provided: 1/2″ in 12″ = 2.38°, OK.

All tendons have the same offset from the girder centerline, therefore, this angle is good for all tendons in WEB A. At interior girders, no horizontal slope is necessary as the blockout is already perpendicular to the tendons.

Also ensure that a minimum of 1′-6″ thickness is provided behind the blockouts as required by Standard Plan B8-5.

Attachment 1

Alternate vertical profile check method (Step 4):

An alternative to the above approach in checking shop drawings is to utilize LOL locations for each tendon to determine a weighted average for the c.g.s. and compare this to the contract plan c.g.s. Therefore, refer to Figure 18 as an example case.

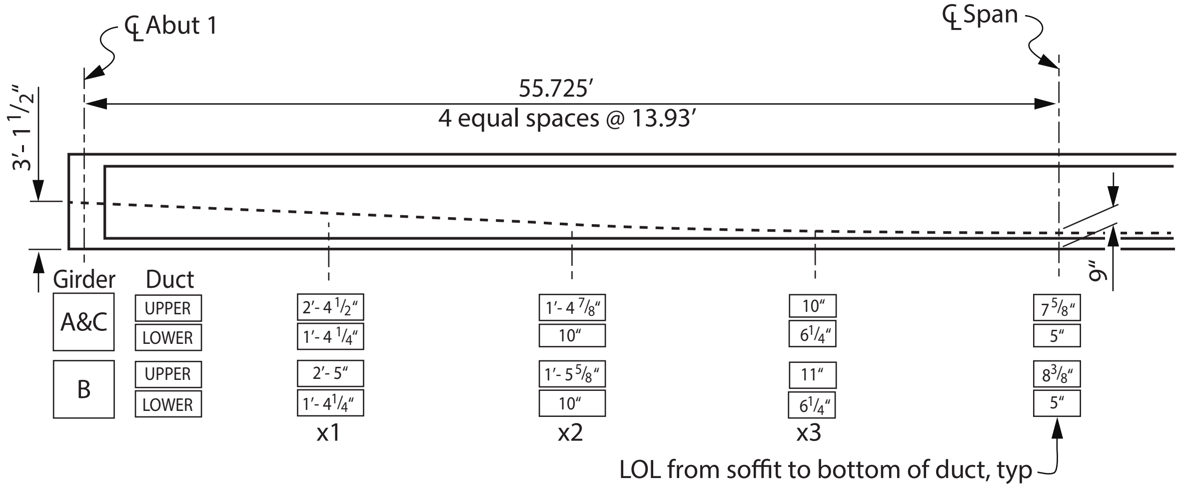

Figure 18 - Single Span Bridge Longitudinal Section (Shop Plan Drawing)

For this single span bridge example, the cable path is symmetrical about the centerline of the span. When shop plans use this format, one needs to compare the c.g.s. location based on the structure plans to the c.g.s. as located by a weighted average of the dimensions provided in the boxes (based on the PS shop plans). One method to perform this check is shown in Figure 19.

Attachment 1

Step 4 Cable path layout check/control points
Intermediate points
Parabola $y = a\,(x-h)^2 + k$

h = 55.725 ft
k = 0.75 ft
a = 0.000765
x1 = 13.931 ft
x2 = 27.863 ft
x3 = 41.794 ft

cg at x1 = 2.086 ft
cg at x2 = 1.344 ft
cg at x3 = 0.898 ft

These are the immediate vertical profile points (soffit to c.g.s.) based on the Structure Plans

These are the immediate vertical profile points (soffit to c.g.s.) as shown in the shop plans

	GIRDERS A&C										GIRDER B											
	Upper Duct					Lower Duct					Upper Duct					Lower Duct						
	No Strands	Soffit to LOL	Duct ϕ	"z"	Soffit to cgs	No. strands	Soffit to LOL	Duct ϕ	"z"	soffit to cgs	No. strands	Soffit to LOL	Duct ϕ	"z"	Soffit to cgs	No. strands	Soffit to LOL	Duct ϕ	"z"	Soffit to cgs	Soffit to C.G.S.	
Shop drawing cg at x1	42	2.375	0.3346	0.052	2.595	44	1.354	0.3346	0.052	1.574	22	2.417	0.3346	0.052	2.637	22	1.354	0.3346	0.052	1.574	2.084	OK
Shop drawing cg at x2	42	1.406	0.3346	0.052	1.626	44	0.833	0.3346	0.052	1.053	22	1.469	0.3346	0.052	1.689	22	0.833	0.3346	0.052	1.053	1.346	OK
Shop drawing cg at x3	42	0.833	0.3346	0.052	1.053	44	0.521	0.3346	0.052	0.741	22	0.917	0.3346	0.052	1.136	22	0.521	0.3346	0.052	0.741	0.909	OK

Figure 19 - LOL Calculations at Intermediate Points

Attachment 1

The soffit to c.g.s. using the shop plans is calculated by using a weighted average of the strand layout line locations provided. Take into account the diameter of the duct and the "z" value for each duct size. Tolerance is ¼″.

The profile of each individual duct may not be parabolic, therefore, plot the layout of each tendon on a graph to ensure there are no kinks in the profile.