Case 1: Bulb Tee Bridge

PROBLEM STATEMENT

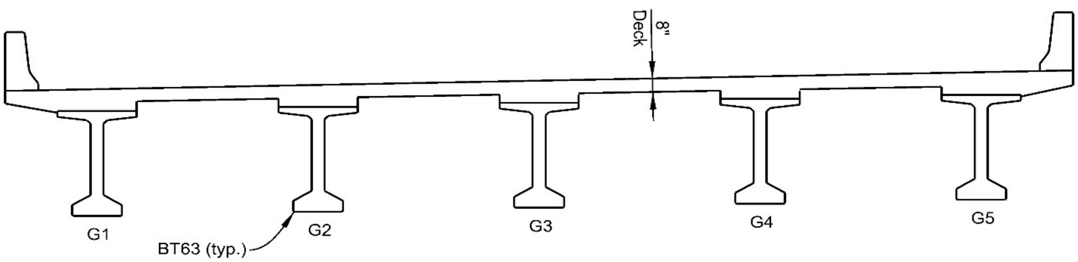
Case 1 illustrates how to set the haunch at supports for a BT girder bridge. Partial depth precast deck panels will be allowed, thus a minimum haunch thickness of 1 in. will be maintained at all locations. At supports, an additional 0.5 in. is provided for construction tolerance, giving a total min. haunch of 1.5 in. required at supports. See Section 5.5.2.1 of this BDM for more information.

The profile grade of the bridge is a crest vertical curve, with the bridge alignment on a horizontal curve with a constant cross-slope. The bridge is supported by chorded girders. The example shows how both the vertical and horizontal deck geometrics affect the deck profile above the girders, and thereby affect the haunch depths.

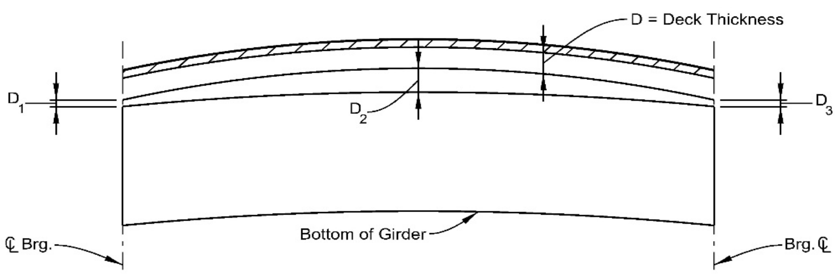
For this example, the design f'c per BDM Section 5.3.1.2 was used for the given predicted girder cambers and DL deflections, not the optional actual values permitted in BDM Section 5.5.2.1.D.

The dead load deflections given in this example do not contain an increase for long-term effects, permissible per BDM Section 5.5.2.1.E of this BDM.

Positive values indicate upward camber or deflection.



Bridge Section View



Girder Elevation View

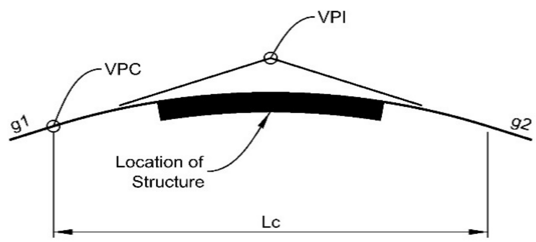
GIVENS

Girder span length, L =	100	ft.
Deck cross-slope, CS =	0.06	ft./ft.
Proposed haunch at CL brg. at CL girder, $D_1 = D_3$ =	3.00	in.
Assumed weighted average haunch for DL, $D_{avg,DL}$ =	5.81	in. (may require iteration)
Girder top flange width, B_{tf} =	43	in.
Dead load deflection, Δ_{DL} =	-1.51	in. (includes superimposed DL)
Predicted girder camber at deck placement, C_{dp} =	3.43	in. (C_{dp} = P/S Camber - $\Delta_{Girder\ Self\ Weight}$)

GIVENS (Continued):

Vertical Curve Data:

Station at VPI =	5+00.00	
Elevation at VPI =	5280	
STA @ CL abut. 1, G1 =	4+50.00	
STA @ CL abut. 2, G1 =	5+50.00	
Curve length, L_c =	400	ft.
Grade in, g_1 =	8.0	%
Grade out, g_2 =	-8.0	%



Horizontal Curve Data:

Radius at G1 CL brg, R = 1275 ft. (may not be equal to radius of HCL)

CALCULATIONS

Step 1: Profile effect due to vertical curve

$$ELEV_x = ELEV_{VPC} + g_1 * x + \left(\frac{r}{2}\right) * x^2$$

$$r = \frac{(g_2 - g_1)}{L_c} \text{ (g in \% and } L_c \text{ in STA)}$$

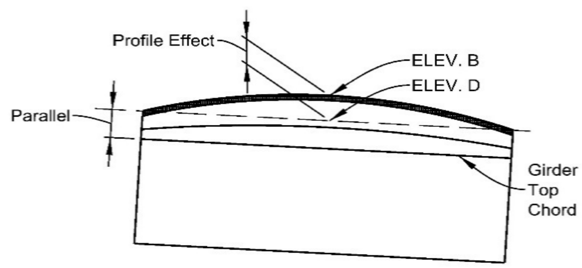
$$ELEV_{VPC} = ELEV_{VPI} - \frac{g_1}{100} * (STA_{VPI} - STA_{VPC})$$

$$STA_{VPC} = STA_{VPI} - \frac{L_c}{2}$$

$r =$ -4.000 %/STA

$STA_{VPC} =$ 3+00.00

$ELEV_{VPC} =$ 5264.00



	X (STA)	g_1*x	r/2*x^2	ELEV	
CL Abut. 1	1.50	12.00	-4.50	5271.50	$ELEV_A$
Midspan	2.00	16.00	-8.00	5272.00	$ELEV_B$
CL Abut. 2	2.50	20.00	-12.50	5271.50	$ELEV_C$

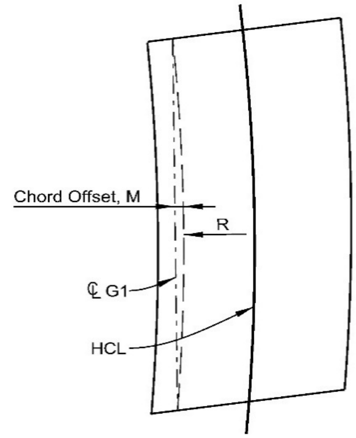
Profile effect 1, $\delta_{PE1} = (ELEV_B - ELEV_D) * 12\frac{in.}{ft}.$

$$ELEV_D = 0.5 * (ELEV_A + ELEV_C)$$

$ELEV_D =$ 5271.50

$\delta_{PE1} =$ 6.00 in.

CALCULATIONS (Continued):



Step 2: Profile effect due to chorded girders

Profile effect 2, δ_{PE2} = $-M * CS * 12 \frac{in.}{ft.}$

Chord offset, M = $\frac{L}{2} * \tan\frac{\alpha}{4}$

Intersection angle of curve along chord, α = $\frac{360 * L}{2\pi R}$

α = 4.49 °

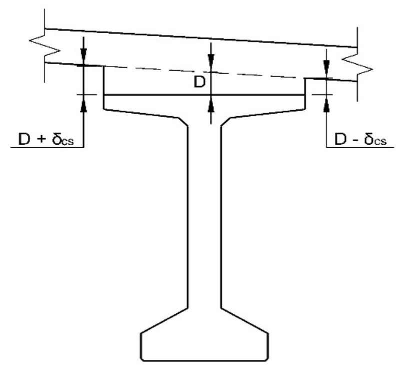
M = 0.98 ft.

δ_{PE2} = -0.71 in.

Step 3: Combined profile effect

Profile effect, δ_{PE} = $\delta_{PE1} + \delta_{PE2}$

δ_{PE} = 5.29 in.



Step 4: Cross-slope effect

Cross-slope effect, δ_{CS} = $\frac{B_{tf} * CS}{2}$

δ_{CS} = 1.29 in. (+/-)

Step 5: Check minimum estimated haunch at supports

Estimated haunch, $D_{1,min}$ = $D_1 - \delta_{CS}$

$D_{1,min}$ = 1.71 in.

OK, $D_{1,min}$ > minimum haunch thickness at supports of 1.50 in.

Step 6: Check estimated haunch at midspan

Estimated haunch at midspan, D_2 = $\frac{D_1 + D_3}{2} - \Delta_{DL} - C_{dp} + \delta_{PE}$

D_2 = 6.37 in. @ CL Girder

Step 7: Verify assumed weighted average haunch for DL

Actual average haunch for DL, $D_{avg,DL}$ = $\frac{(D_1 + 10 * D_2 + D_3)}{12}$ BDM Eq. 5-1

$D_{avg,DL}$ = 5.81 in.

OK, $D_{avg,DL}$ matches assumed average haunch used for dead loads

Note: D_2 may be used as the haunch thickness at midspan for the following items:

- Calculating Δ_{DL} reported on the girder sheet and used in setting deck elevations
- Calculating haunch concrete quantities

CALCULATIONS (Continued):

Step 8: Calculate camber tolerances per BDM 5.5.2.1.D

Over-camber tolerance, δ_{over} = $0.20 * C_{dp} \geq +1.0$ in.
δ_{over} = 1.00 in.

Under-camber tolerance, δ_{under} = $-0.50 * C_{dp} \leq -1.0$ in.
δ_{under} = -1.72 in.

Step 9: Account for over-camber

Minimum haunch at midspan, $D_{2,over}$ = $D_2 - \delta_{over} - \delta_{CS}$
$D_{2,over}$ = 4.08 in. (at edge of flange)

OK, $D_{2,over}$ > minimum haunch thickness of 1.00 in. if girders over-camber by 20%

Step 10: Account for under-camber

Maximum haunch at midspan, $D_{2,under}$ = $D_2 - \delta_{under}$
$D_{2,under}$ = 8.08 in.

Weighted average haunch for DL, $D_{avg,DL,under}$ = $\frac{(D_1 + 10 * D_{2,under} + D_3)}{12}$ BDM Eq. 5-1

$D_{avg,DL,under}$ = 7.24 in.
DL defl. (revised using $D_{avg,DL,under}$), $\Delta_{DL,under}$ = -1.58 in. (from software)
Residual camber = $C_{dp} + \delta_{under} + \Delta_{DL,under}$
Residual camber = 0.13 in.

OK, girder maintains positive camber if under-cambered by 50%

Note: Girder has been designed for all strength and service criteria using the following:

- $D_{2,under}$ as the haunch at midspan for composite section properties
- $D_{avg,DL,under}$ as the weighted average haunch thickness for dead load
- Girder design compressive strength, f'c per BDM Section 5.3.1.2

CONCLUSION

A proposed haunch of 3 in. at CL of girder at supports passed all required checks. The haunch at supports was intentionally minimized to avoid an excessively thick haunch at midspan.

The example shows how a crest vertical curve adds to the haunch thickness at midspan and, in this case, results in a thicker estimated haunch at midspan than at supports. The haunch thickness at midspan is partially offset by the apparent sag effect of chording girders on a horizontally curved bridge deck.

Other geometric situations that will impact the haunch depth include flared girders and deck cross-slope transitions.