3.3.12 Camber Design for Plate Girders

Typical slab-on-beam bridges have space between the bottom of the slab and the top of the top flanges of beams. This space, referred to as the fillet or haunch by IDOT, typically consists of unreinforced concrete that increases the dead load of the section but is not normally considered to add strength. Excessive fillets are considered problematic and, if greater than 6 in. in depth, require reinforcing. See Section 3.3.9 of the Bridge Manual. It is common practice to minimize the depth of fillets by cambering plate girders while rolled beams are only cambered occasionally. For plate girder structures, cambering is most commonly achieved by cutting the top and bottom of the web to achieve predetermined curves. This design guide gives the designer a step-by-step process for determining these curves.

Camber Design Procedure, Equations, and Outline

Determine Necessary Number of Camber Diagrams

Based on the profile grade, determine the theoretical top-of-deck elevations for each beam at ten ft. intervals along the beam. These elevations are dictated by the profile grade, horizontal curve data, and crown. If the theoretical top-of-deck elevations have similar vertical curves for each beam, and all girders in the bridge have similar deflected shapes, only one girder need be detailed for camber with all others cambered identically. This is typically the case for any bridge that avoids the following scenarios:

1. Curved girders, where the radius of curvature is less than 1,200 feet
2. Highly skewed structures
3. Structures with non-parallel substructure elements
4. Non-uniform dead loads (large or eccentric median or sidewalk loads, sign structures or light poles attached to bridge, etc.)
5. Flared girders or partial length girders
6. Large superelevation transition

For cases such as 1 through 6 above, separate camber diagrams are required for all girders that are not within a ¾ in. tolerance of a girder that is already cambered.

Determine Number and Location of Camber Definition Points

Girder segments are defined as fabricated girder elements bounded by beam ends, field splices, and pin/link hangers. Examples of beam segments include (but are not limited to): abutment to splice, splice to splice, abutment to abutment (no splice), and pin/link hanger to splice.

Camber shall be defined at a minimum of three points within a girder segment. These points should be positioned to adequately define the curve, including the maximum distances from end-to-end chords and any inflection points. The objective is to provide adequate information for the fabricator to able to construct the correct curve. As such, some engineering judgment is required when choosing points to report on a camber diagram.

At each camber definition point and at segment ends, the following information is calculated:

1. Theoretical top-of-deck elevations
2. Distance from top-of-slab to top-of-web, which includes slab thickness, ¾ in. minimum fillet, top flange splice plate (if applicable), and top flange thickness
3. Dead Load (DC1) deflections of the non-composite section due to self-weight and weight of slab and fillet

Determine the Maximum Adjusted Top-of-Web Elevations and Camber

At each camber definition point and at beam ends, the maximum adjusted top-of-web elevations are calculated as follows:

1. Subtract the top-of-slab to top-of-web distances from the theoretical top-of-deck elevations. This results in the maximum top-of-web elevations.
2. Add the DC1 deflections to the maximum top-of-web elevations. Downward deflections are taken as positive, upward deflections as negative. This results in the maximum adjusted top-of-web elevations.
3. Using the maximum adjusted top-of-web elevations at the ends of each segment, interpolate linearly to calculate what the elevations would be at each camber

definition point. When drawn out, this interpolation should give a straight line from one segment end to the other.

4. At each camber definition point, subtract the straight line interpolation value determined above from each maximum adjusted top-of-web elevation. This gives the required camber at each point. A positive number represents camber in the upward direction, while a negative number represents camber in the downward direction.

If the required camber is less than ¾ in. for the entire segment, the segment need not be cambered.

Plot the Camber Diagram

The camber diagram, when plotted, should show the approximate shape of the curve made by the maximum adjusted top-of-web elevations. It should also show the straight-line interpolation between segment ends, the locations of the camber definition points, and the camber at each camber definition point.

It is important that the camber diagram follows a smooth curve. Therefore, if necessary, the camber at each location may be varied slightly to allow for a smooth curve. See the calculated and chosen camber diagrams presented in the following example for an illustration of this concept.

Camber is detailed to a tolerance of ¼ in.

Camber Design Example: Two-Span Plate Girder

Bridge Data and Top-of-Slab Elevations

Span Lengths: Two equal spans of 98.75 ft.
Number of Beams: 6

No horizontal curve, normal crown, zero skew, no appurtenances

CL Bearing Abutment 1:   Station 374+54.25, Elevation 471.00

CL Bearing Pier: Station 375+53.00, Elevation 471.51

CL Bearing Abutment 2:   Station 376+51.75, Elevation 471.61

Profile Grade Data

PVC: Station 374+55.00, Elevation 471.01

PVI: Station 375+92.50, Elevation 472.00

PVT: Station 377+30.00, Elevation 471.40

Steel Section Data

Top Flange Thickness: 1 in. for 76.75 ft. from CL Brg. Abut. 1,

                         1.75 in. for remaining 22 ft. in Span 1,

                         Span 2 symmetrical about CL Brg. Pier

Splice Location: 76.75 ft. from CL Brg. Abut. 1

Top Flange Splice Plate Thickness: 0.8125 in.

Determine Necessary Number of Camber Diagrams

The bridge does not have any conditions which would cause dissimilar vertical top-of-slab curves or deflected girder shapes. Consequently, only one camber diagram need be calculated which is applicable to each girder.

Determine Number and Location of Camber Definition Points

The girder is divided into two segments: CL Brg. Abut. 1 to CL Splice (Segment 1), and CL Splice to CL Brg. Abut. 2 (Segment 2):

Segment 1 does not contain any changes in section. Therefore, the minimum of three camber definition points will be used at quarter-points of the segment.

Segment 2 does contain a change in section. The top flange transitions from 1.75 in. flange thickness to 1 in. flange thickness at a distance of 44 ft. along the segment. Therefore, camber will be defined at the quarter points along each section (44 ft. and 76.75 ft.) and at the location of section change, for a total of seven camber definition points.

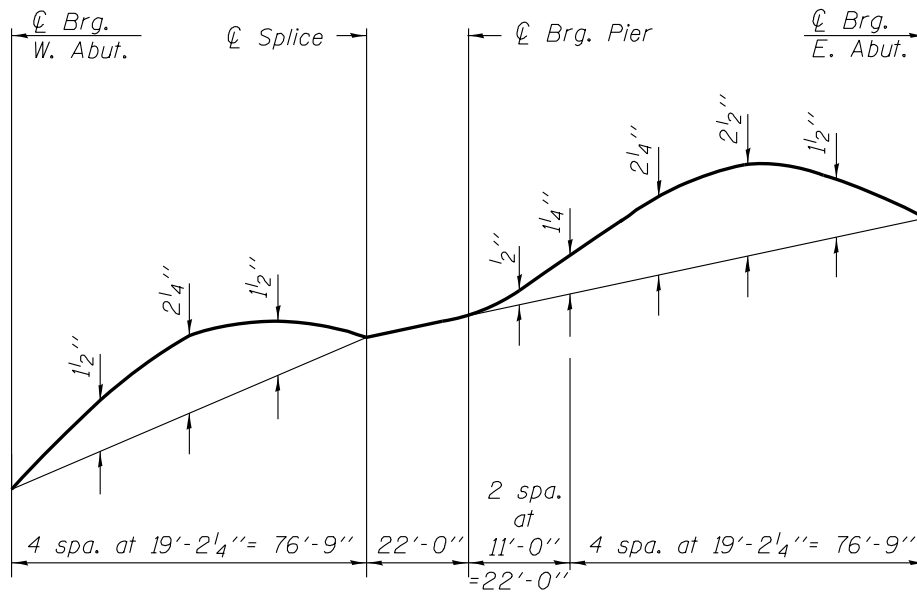*Determine the Maximum Adjusted Top-of-Web Elevations and Exact Camber*

Tabular camber calculations for Segment 1 are given below and are followed by calculations for Segment 2. Calculated and chosen design camber diagrams are presented at the end of this example.

	CL Br. Abut. 1	Pt. 1	Pt. 2	Pt. 3	CL Splice
Camber Definition Point Location (ft.)	0.00	19.19	38.38	57.56	76.75
Theoretical Top-of-Slab Elevation (ft.)	470.689	470.821	470.937	471.037	471.122
Slab Thickness (ft.)	0.667	0.667	0.667	0.667	0.667
Minimum 0.75 in. Fillet (ft)	0.063	0.063	0.063	0.063	0.063
Top Flange Thickness (ft.)	0.083	0.083	0.083	0.083	0.146
Top Splice Plate Thickness (ft.)					0.068
DC1 Deflections (ft.)	0.000	0.079	0.115	0.093	0.039
Maximum Adjusted Top-of-Web Elevation (ft.)	469.877	470.088	470.240	470.317	470.218
Straight-Line Interpolation Elevation (ft.)	469.877	469.962	470.047	470.133	470.218
Exact Camber (in.)	0.00	1.51	2.30	2.21	0.00

	CL Splice	Pt. 1	Pt. 2	Pt. 3	Section Transition	Pt. 4	Pt. 5	Pt 6.	CL Abutment 2
Camber Definition Point Location (ft.)	0.000	11.00	22.00	33.00	44.00	63.19	82.38	101.56	120.75
Theoretical Top-of-Slab Elevation (ft.)	471.122	471.164	471.200	471.232	471.258	471.292	471.311	471.314	471.301
Slab Thickness (ft.)	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667
Minimum 0.75 in. Fillet (ft)	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
Top Flange Thickness (ft.)	0.146	0.146	0.146	0.146	0.146	0.083	0.083	0.083	0.083
Top Splice Plate Thickness (ft.)	0.068								
DC1 Deflections (ft.)	0.039	0.013	0.000	0.013	0.039	0.093	0.115	0.079	0.000
Maximum Adjusted Top-of-Web Elevation (ft.)	470.218	470.302	470.325	470.370	470.422	470.572	470.614	470.581	470.489
Straight-Line Interpolation Elevation (ft.)	470.218	470.243	470.268	470.292	470.317	470.360	470.403	470.446	470.489
Exact Camber (in.)	0.00	0.70	0.69	0.93	1.26	2.55	2.53	1.62	0.00
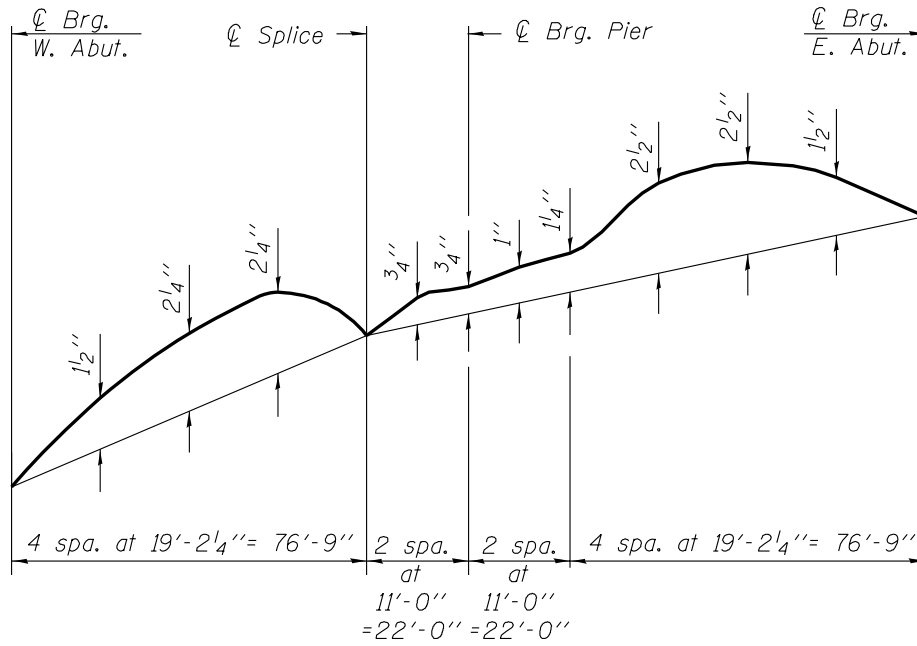
CALCULATED CAMBER

CHOSEN CAMBER