

6.10.3 Constructibility Considerations for Steel Plate Girder Bridges

There are several constructibility issues that are unique to steel plate girder bridges that designers should account for in the design, plan preparation, and shop drawing review stages of a project.

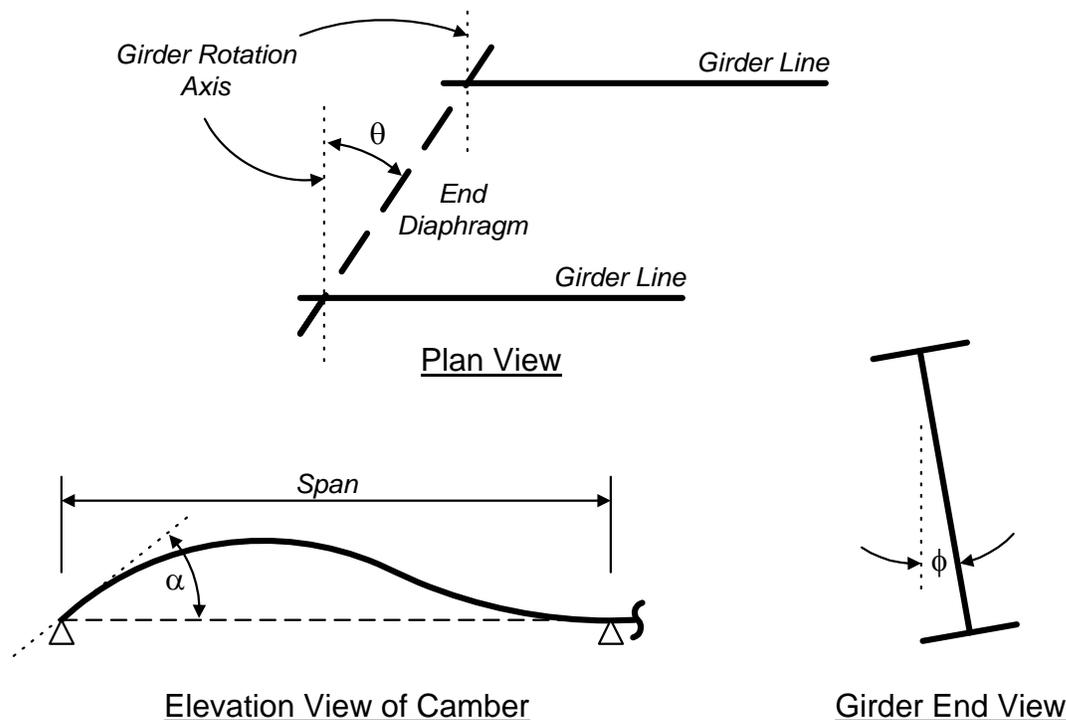
Diaphragm Installation for Skewed Bridges:

On straight non-skewed bridges all girders across the width of the bridge rotate at their bearings about a single axis line which is perpendicular to the girders, therefore as each girder is loaded all the girders rotate about a common line and the end diaphragms that connect the girders are unaffected. On skewed bridges each girder rotates about its own axis offset from adjacent girders, consequently as the girders are loaded and the girder ends rotate a distorting force is induced in the end diaphragms that connect the girders, since the diaphragms are very stiff diagonally and the girders are relatively flexible torsionally the diaphragms will twist the girders, pulling the web out of plumb.

The angle that the girder web is twisted out of plumb can be calculated as follows:

$$\phi = \alpha \tan(\theta)$$

where: ϕ = the out-of-plumb angle
 θ = the bridge skew angle
 α = the angle of the end of the girder due to the dead load camber (other than girder self weight)



While there is no way to prevent girder twisting without the complete removal of diaphragms, when and how the girders twist can be controlled by the way the girders are detailed and fabricated. If the girders and diaphragms are detailed and fabricated for the diaphragms to fit the initial position of the girders, before the bridge deck is placed, then the girders will be plumb when the erection is complete. However, after the deck is placed, the girders will be twisted permanently in their final position, the girders will not sit level on the bearings and high distortional stresses will be locked into the diaphragms and girders. The only advantage to this method is that the girders and diaphragms fit initially, making it easier for the contractor to assemble.

On the other hand, if the girders and diaphragms are detailed and fabricated for the final position then the girders will need to be twisted out of plumb initially in order to get the diaphragms installed. However, after the deck is placed, the girders will be plumb for their final permanent position with a minimum amount of permanent distortional stresses in the diaphragms and girders. Standard practice for ITD is to detail diaphragms for the final position. Since some fabricators detail for the initial fit all shop drawings should be carefully checked to ensure they conform to the plans and the design. It is also good practice to specify the direction of the deck placement on the plans. The girders will initially be out of plumb to the greatest extent at the ends of the girders so the deck placement should progress from the dead load inflection point of the span toward the end of the girders so that the girders are near plumb by the time the placement reaches the girder ends.

There is a similar effect from intermediate diaphragms on skewed bridges. Because intermediate diaphragms are typically detailed to attach to the girders such that the diaphragms are perpendicular to the girder lines, they connect adjacent girders at slightly different span points. Since the amount of camber is different at each of these points the girders will need to twist initially out of plumb if the diaphragms are detailed to fit in the final deflected position. But, like the end diaphragms, once the deck has been placed the girders at the intermediate diaphragms will be in the correct upright position.

Camber Differences of Interior and Exterior Girders:

Interior and exterior girders for a given span are often designed for different amounts of dead load due to different tributary areas. This can result in a difference in the dead load camber shown in the plans for interior and exterior girders. However, if the girders are fabricated with different cambers it may become difficult to install the diaphragms during erection, but more importantly the deck may not be finished to the desired thickness across the full width of the bridge. Typically the screed rails for deck finishing machines are supported by the exterior girders, therefore if the exterior girders have more or less camber than the interior girders the deck will either be screeded too thick or too thin over the interior girders since the girders will not yet be fully loaded and therefore not in their final deflected position at the time the screed is finishing the deck. Even though it is appropriate to design the interior and exterior girders for different dead loads for the strength limit state, the dead load camber should be based on the dead load distributed equally to all girders so that all girders are cambered the same. This is really more representative of how the girders will actually deflect during construction as they are all connected to each other by diaphragms.

Bearing Alignment and Changes in Girder Length:

Bearings are often designed to accommodate the movement of girders for such effects as temperature change and live load rotations, but bearings should also accommodate construction tolerances and the length change that occurs in the bottom flange of girders between the initial unloaded condition and the final fully loaded condition.

While there are two construction tolerances to consider: 1) girder length, and 2) bearing placement on abutments and piers, there are also two parts to bottom flange lengthening: 1) the elastic lengthening due to the strain in the bottom flange resulting from the applied loads, and 2) the geometric change in the effective horizontal length of the girder due to the flattening of the fabricated camber. Typically most of the lengthening is the result of elastic strain while the effect due to the flattening of the camber is usually minor and can be ignored in most cases, however camber flattening may become significant when there is a large amount of total camber constructed in the girder.

Accommodating the various factors that contribute to nonalignment of sliding bearings is relatively straight forward since the sliding surface can just be increased. However for elastomeric bearings without a sliding surface it becomes more difficult because the bearings need to be designed to accommodate the extra lateral displacement by increasing the elastomer thickness. This in turn can affect other bearing properties such as load capacity, stability and vertical deflection. To avoid potential problems due to these issues, rather than increasing the elastomer thickness, the contractor can be required by specification to jack the girders and reposition the bearings after all dead loads have been applied and the temperature is near the midpoint of the design range.

Lateral Deflections of Exterior Girders due to Deck Overhang Brackets:

The construction of deck overhangs on steel girders is usually done with the use of standard deck overhang brackets. The use of these brackets introduces a torsional load into the exterior girders during placement of the concrete deck and the potential exists for the girder to rotate laterally, resulting in excessive overhang deflections. This can adversely affect finished grades

when the screed rail is placed at the end of the overhang, the resulting deflection causes the screed to finish the deck lower than anticipated across the full width of the bridge. In order to minimize this problem all steel girder bridges should be checked for exterior girder rotational deflections due to overhang brackets. Anytime the calculated deflection at the edge of the overhang due to torsional effects exceeds 0.20" a revision should be made in the plans to reduce the deflection, such as closer diaphragm spacings, a larger top girder flange, or smaller overhangs. When the structural details cannot be altered temporary girder bracing should be detailed in the plans to resist the rotational effect. For more information on analyzing torsional loading refer to Article 6.10.3.4 and Appendix 6.1 of the Bridge Design LRFD Manual or to the Kansas Torsional Analysis of Exterior Girders method found on the Bridge Design X-Drive or available from KDOT.

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Added new article