6. STEEL STRUCTURES

Economics – For three span structures, an economical span ratio is 1:1.3:1. For four span structures an economical ratio is 1:1.25:1.25:1.

Haunches are costly to fabricate and should only be used for rare situations. In general the AASHTO/NSBA "Guidelines for Design for Constructability" should be followed.

All structures should have a minimum of three girder lines, although four lines are preferred.

6.1 General Design Philosophy

In general, structural steel superstructures are shallower and lighter than concrete superstructures. In addition to long span and specialty structures, steel superstructures should be considered where foundations are expensive or where a change in superstructure height has significant cost implications on the approaches.

Girders should be designed to be composite with the concrete deck throughout the entire girder length. Shear connectors, in the form of shear studs shall be provided in both positive and negative moment areas and over field splices.

During design, it may be assumed that the dead load of the steel beam or girder is 15% larger than that computed using only the flanges and web. This is a reasonable estimate for the weight of stiffeners, diaphragms or cross frames and connections.

For large structures a web depth study should be performed to arrive at the optimal girder height.

6.2 Materials

Structural Steels

Steel bridges are fabricated and constructed with steel elements that are produced at two different types of steel mills; shape mills and plate mills. In addition to different products, the grades of steel available from each type of mill differ slightly.

Plate mills produce flat sections that are used to fabricate plate girders, connections, gusset plates, etc. Plate steel is also produced in a number of different material specifications. Larger plate mills have a width limitation of 150 inches. The maximum available plate length varies by mill and cross-sectional dimensions of the plate.

Bolts, Nuts, and Washers

Bolted connections should generally use 7/8 inch diameter bolts, as specified by AASHTO M 164.

For applications where strength is not the primary design consideration, ASTM A307 bolts may be used.

Welds

Typically, only fillet welds and full penetration welds are permitted. Weld designs should be based on E70 filler material.

With the exception of pile splices, shear connectors, and railroad ballast plate splices, field welding is not used or permitted.

Additional references are the ANSI/AASHTO/AWS "Bridge Welding Code - D1.5", and "Welding of Steel Bridges", Vol. I, Chapter 15, Highway Structures Design Handbook.

Bearings

Steel plates used in the fabrication of bearings shall be Grade 36, 50, or 50W.

6.3 General Dimensions and Details

Designers should provide simple details that are easily fabricated and do not sacrifice the integrity of the bridge. Details that trap water or produce an environment that is conducive to corrosion should be avoided. In addition, details with inadequate clearances are difficult to fabricate and erect.

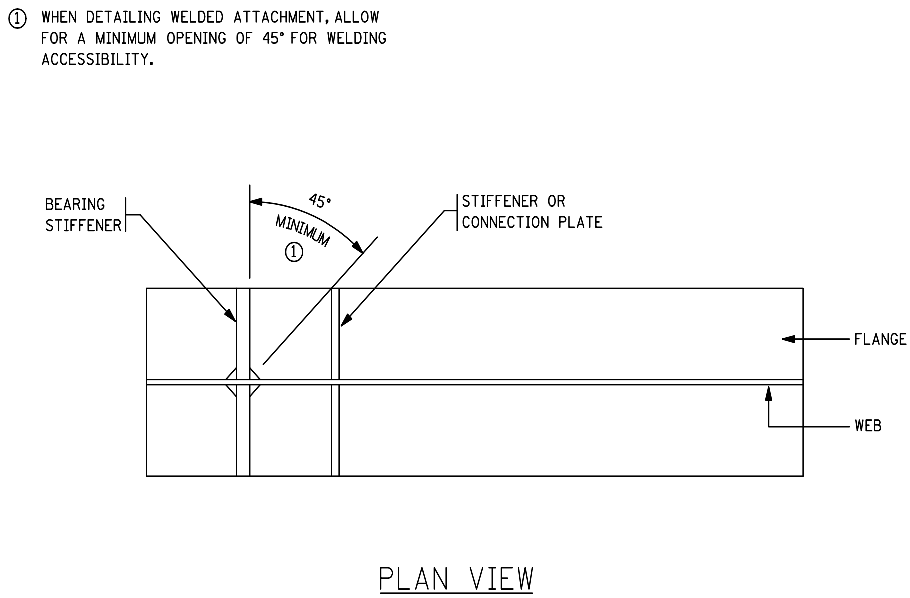
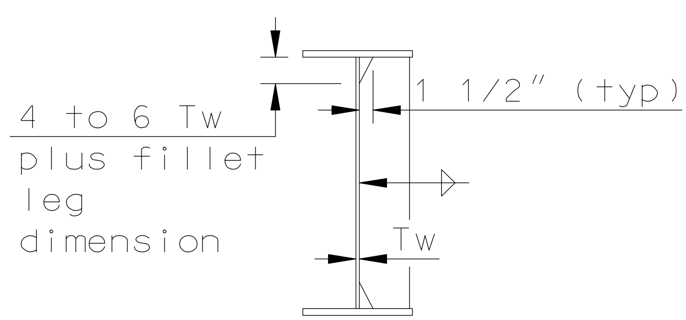


Figure 6.3.1

Stiffeners, Transverse and Bearing
Single or paired transverse stiffeners may be used. For paired stiffeners, the same details as shown for a single stiffener should be used. When longitudinal stiffeners are required, all transverse stiffeners should be placed on one side of the web, and the longitudinal stiffener placed on the opposite side.



Fillet weld (both sides) to both flanges when used as a cross-frame or diaphragm connection plate. Otherwise, a tight fit to tension flanges and fillet weld to compression flanges should be used. As an option, when the stiffener is not used as a connector plate, the stiffener may be cut short from the tension flange by a distance equal to the vertical leg of the cope. For bearing stiffeners at piers and abutments, both sides of the stiffener shall be fillet welded to the top flange, milled to bear and fillet welded to the bottom flange. The same cope dimensions as used for transverse stiffeners should be used.

Welded Steel Girders

No flange plate should be less than ¾ inches thick nor less than 12 inches in width. Plate sizes should be as controlled by product availability in the AISC Manual of Steel Construction and availability from suppliers. The use of hybrid girders is not recommended. Optional field splices should be provided on the plans if deemed necessary or practical. Tension members should meet the longitudinal Charpy V-notch Zone 2 test. Top and bottom flanges may be different sizes at the piers.

Structural steel plans and details should clearly describe the material to be used for each structural steel component. Even for projects where structural steel is paid for on a lump sum basis, informational quantities should be provided in the plan set to quantify the amounts of different steels incorporated into the project.

Welding is used in many locations during the fabrication of plate girders. It is used to connect:

- Web plates to flange plates
- stiffeners and connection plates to web plates
- stiffeners and connection plates to compression flanges

Figure 6.3.2 identifies the locations of these welds and the appropriate fatigue category to be used for checking live load stress ranges.

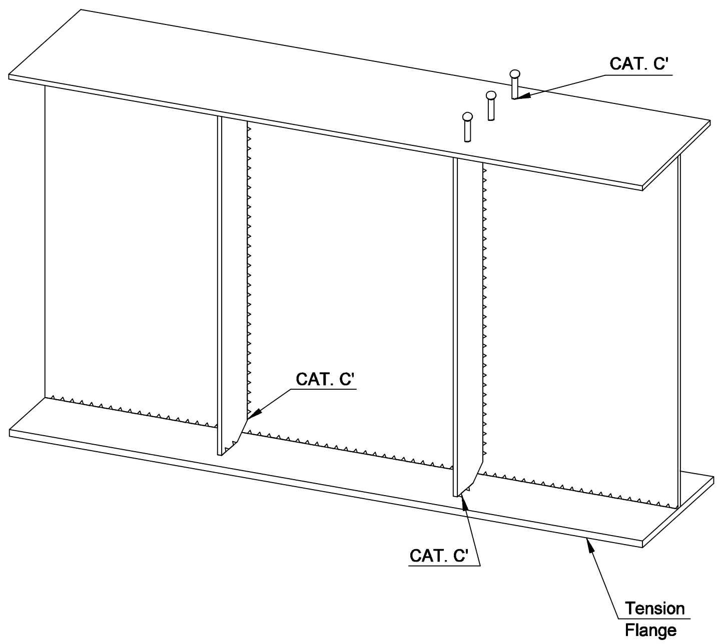


Figure 6.3.2

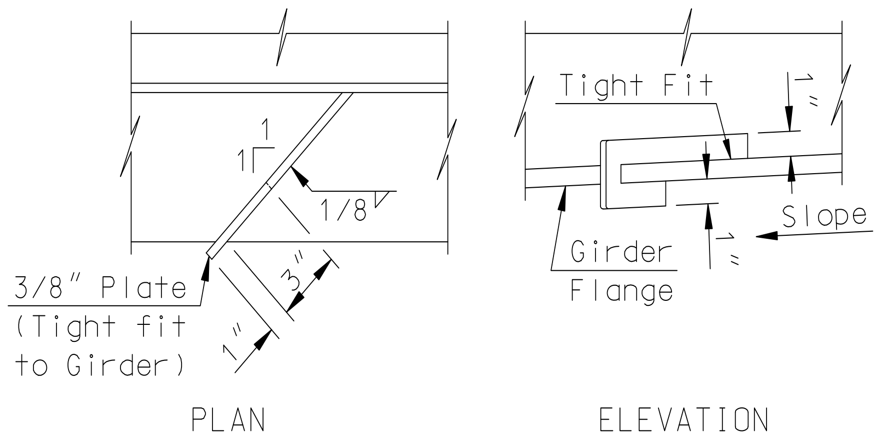
Field splices shall be located at or near points of dead load contraflexure.

The LRFD Specifications do not explicitly give a maximum diaphragm spacing as was previously given in the Standard Specifications. The spacing of diaphragms used for bracing is used to determine allowable compressive stresses. Maximum diaphragm spacing is 25 feet. If the span length is not divisible by 25 feet use 25 foot spacing in the positive bending area and the smaller area near the pier.

[C6.10.3.2.1] The segment length to top flange width ratio should be limited to a ratio of 85 for stability during shipping and erection.

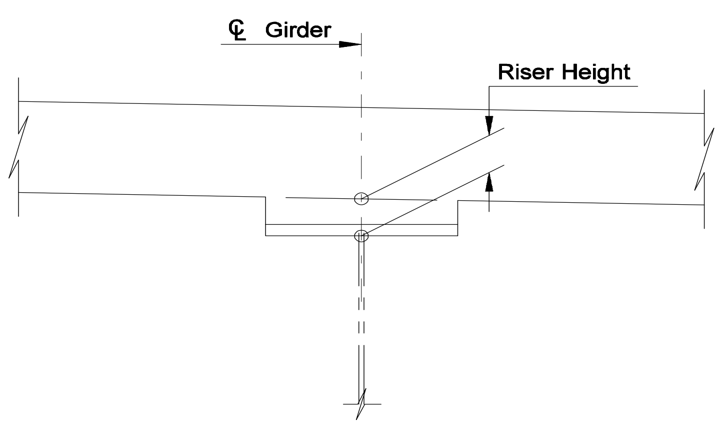
Drip Plate

Drip plates should be used on all weathering steel girder bridges. Drip plates should be placed 5' from the faces of supports to avoid staining the concrete. Drip plates should be placed on the outside of the exterior girders on the up-grade side of all supports. See details below.



The beam shall be painted 10 feet from each open joint.

Risers are used with steel superstructures to provide a construction tolerance for the profile of the deck. The riser should have vertical edges that are flush with the edges of the top flange. The riser is defined as the distance between the bottom of the deck and the top of the web. The minimum height or thickness for the concrete portion of the riser is 1 inch. The minimum should be provided at the edge of the flange taking into account the cross slope of the deck. At field splices check that the top plates do not penetrate the bottom of the deck by more than ½".



Structural steel quantities are computed by finding the weight of steel beams or girders, diaphragms, cross frames, and all other plates (e.g., sole and gusset plates).

When sizing stiffeners and connection plates, a limited number of thicknesses should be used. Connection plates must be a minimum of ½" x 7½" to permit two lines of bolts.

Bent plate diaphragms shall be provided for the following cases:

- rolled beam superstructures
- plate girders with depths less than 48 inches
- beam depth to lateral spacing ratio less than 0.40

In other cases cross-frame diaphragms should be used.

6.3.1 Shear Connectors [6.10.7.4.1]

Seven eighths inch diameter stud connectors that extend above the bottom mat of deck reinforcement shall be provided.

6.3.2 Fatigue

For all Highway bridges, details for a 75 year fatigue life level shall be checked regardless of ADT level.

[6.10.8.1.1]

Top and bottom transverse stiffeners are typically coped 1½ inches from face of web and 2½ inches from face of flange.

6.3.4 Camber

For most steel bridges camber will be fabricated into the beam to offset the deflections due to applied dead loads. The cambered member is fabricated with a profile opposite of that caused by dead load deflection.

For rolled beams introducing camber can be a relatively expensive operation. The beam should be placed "natural camber up".

Plate girders shall always be cambered. This is accomplished without mechanical means or heat straightening techniques. Vertical cambers are introduced by cutting the web plates with the desired profile. Horizontal curvature is introduced by cutting flange plates with the proper horizontal shape. During fabrication, the web and flanges are attached to each other to produce a member with the proper geometric characteristics.

Girders should be cambered for anticipated dead load deflections and vertical curve. The deflection due to future wearing surface (FWS) shall be included.

Camber information should be included in the plans and presented in fractions of an inch ($^1/_{16}$ inch precision). A table and schematic detail should be used to convey the information. Within the schematic detail, the horizontal reference line, chord lines connecting field piece ends, and the camber curve should be labeled. Tabularized information at field splices, support points, and at intermediate points along the length of field pieces should be provided. Each field piece should be defined by at least five points that are uniformly spaced at intervals between 5' and 20'. Points of maximum camber should be defined.

6.4 Plate Girders

Plate thicknesses in $^1/_{16}$ inch increments for thicknesses up to 1 inch should be selected. For thicknesses between 1 and 3 inches, $^1/_8$ inch increments should be used. For thicknesses between 3 and 4 inches, $^1/_4$ inch increments should be used.

In general, additional web thickness increases shear capacity. An increase in web height or flange area increases moment capacity and reduces live load deflections.

In general, these guidelines should be followed in plate size selection for plate girders:

Flanges
For plate girder flanges, the minimum size is ¾" x 12".

The width of the flange should not change at a welded butt splice. The change in flange area at butt weld splices should not exceed 100%. In general it is economical to provide a butt splice if 800 lbs. or more of steel can be saved.

In negative moment areas, equal top and bottom plate sizes should be selected. Where practical, the bottom flange should be kept a constant width over the entire girder length. Top flanges should be kept a constant width within each field piece. If changing the top flange width at a field splice, the flange width should not be tapered.

WEB
For web plates the minimum thickness is ½ inch. The ½ inch web reduces the potential for warping during fabrication.

For continuous structures the web should be sized to be $^1/_{16}$ th of an inch thinner than a web which requires no stiffeners for shear.

Longitudinal stiffeners should only be considered for girders over 84 inches deep. The stiffeners should be terminated at a low stress point with a fatigue resistant detail. Generally, longitudinal stiffeners should be continuous through transverse and bearing stiffeners.

6.4.1 High Performance Steel Girders

Girders using High Performance Steel (HPS) (F_y = 70 ksi), can be an economical alternate to girders using 50 ksi steel.

6.5 Curved Girders

The LRFD Specifications do not cover the design of curved bridges. Curved bridges should be designed in accordance with the 2003 AASHTO Guide Specification for Horizontally Curved Steel Bridges.

6.6 Bolted Connections and Splices

Most structural connections or splices should be detailed with $^7/_8$ inch diameter M 164 bolts. The typical bolt pattern is a 3-inch grid with 1 $^1/_2$ inch edge distances.

The change in flange area at bolted splices should not exceed 100%. The splice plates should be of the same steel as the elements being connected. The minimum thickness of splice plates is $^5/_{16}$ inches.

Bolted field splices should be designed as slip-critical connections. Assume that the threads are not included in the shear plane and that a Class A surface coating or condition is available for slip resistance (Slip Coefficient 0.33). Faying surfaces should be primed the same as the rest of the beam.