Chapter 3

Superstructure Design

Introduction

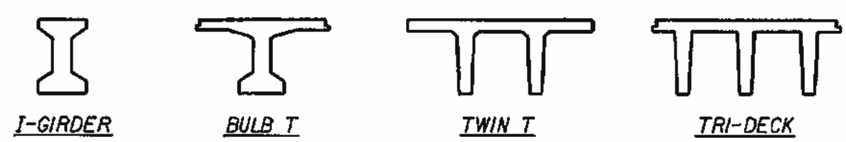
This chapter provides guidance for the design of steel (rolled beams or welded plate) girders and concrete (prestressed-precast and cast-in-place) girders.

Superstructure Types

Rolled beam girders (W Girders) are manufactured steel sections typically used for short span(s) and/or tight vertical clearance situations. An example is W 27 x 94, where W is the designation for wide flange, 27 is the approximate girder depth in inches, and 94 is the weight of the section per linear foot in pounds. The usual depth of rolled beam girders ranges from a W 24 to a W 40. This superstructure type is typically the easiest to design and detail. Design bridges with rolled beams using decimal dimensions listed in the AISC Manual of Steel Construction.

Welded plate girders are fabricated steel sections comprised of web and flange plates welded into an I configuration. Welded plate girders are typically used for longer span(s) and curved girders.

Prestressed-precast concrete sections are fabricated girders of various sizes and shapes. Examples of those most commonly used are I-Girders, Bulb T's, Twin T's, and Tri-decks, although other sections are available and may be used.



Steel Girders Materials

Steel used in the fabrication of superstructures shall be ASTM A709 Grades 36, 50, 50W or HPS 70W. ASTM A992 may be used for non-weathering steel rolled sections. Currently, hybrid girder construction shall be avoided due to small differences in material costs, except when using high performance steel. The use of high performance steel will need approval from Bridge Program Staff before being used in a design.

Steel Girders General Design

Simple span bridges should be designed as composite. Multi-span bridges with a total length of 200 ft or less should be designed as non-composite. Bridges with lengths greater than 200 ft or with spans greater than 100 ft should consider composite design.

Composite structures should be considered to help reduce girder depth in cases of limited vertical clearance and in areas where the grade raise must be minimized. The use of full length composite structures should only be considered in special cases.

Full or partial composite structures shall be analyzed (determination of member actions and reactions) for stage one loading using the steel girder section only. Analysis for subsequent stages of loading (stages 2 and 3) shall be performed using the steel section and the concrete deck for the entire length of the structure. The structural design of composite girders and slabs shall be based on the composite moment of inertia of both the steel section and the concrete deck for positive bending and the steel section and reinforcing steel in the concrete deck for negative bending. When no shear connectors are present the design should be based solely on the steel girder section.

The following guidelines shall be used for the design of negative moment regions of composite structures. If the bridge is composite full length, use the deck reinforcing and slab as part of the negative moment section. If the bridge is non-composite over the intermediate supports, use only the girder section. Ideally, composite sections will only be located in positive moment regions.

The top flange for non-composite girders should be embedded full depth into the bridge deck, when possible or ¾" at centerline girder, whichever is less. For composite girders, the flange should not be embedded into the deck.

Automatically end welded studs are to be used as the connection between the girder and slab for developing the shear resistance necessary to produce composite action. Shear studs are ¾" or 7/8" diameter and 4" long.

Composite girders and slabs shall be designed for the appropriate composite moment of inertia, based on the corresponding loading stage and shall be consistent with the predetermined properties of the various materials used.

The ratio of the modulus of elasticity of steel to that of concrete for various design strengths shall comply with the following provisions.

> The effect of creep shall be considered in designing composite girders that have dead loads acting on the composite section. The effect of creep on composite structures shall be computed from "n" multiplied by three. The value of "n" shall be as shown in Chapter 1.

Composite sections should preferably be proportioned so that the neutral axis lies within the steel girder. If concrete is on the tension side of the neutral axis, it shall not be considered in computing moments of inertia or resisting moments except for deflection calculations.

A design is required for the controlling girder with the largest combined dead and live load. The same girder section is to be used for both the interior and exterior girders.

Constructability checks should be done for both the interior and exterior girders. Steel girders shall be investigated for stability and strength during the time the concrete is in place and before it has hardened. Girders shall be designed so that temporary supports are not required during placement of concrete.

Maximum compressive and tensile stresses in girders shall be the sum of the stresses produced by the dead loads acting on the steel girders alone and the stresses produced by the superimposed loads acting on the composite girder.

In addition to meeting the basic design criteria, members and fasteners subject to repeated variations or reversals of stress shall be designed for fatigue.

Haunch girders are welded plate girders with a deeper web plate over the piers to accommodate the larger negative moment of longer span bridges. These girders require an additional detail showing the limits and dimensions of the parabola, arc, and a flat bearing section.

Steel Girders Spacing

The following table should be used as a starting point to determine the number of girders and girder spacing to be used with curbs. If a sidewalk is used or if other conditions exist, the number of girders and spacing will require modification; however, for rolled beam girders, the cantilever shall not exceed 3'-0". Girder spacing should be specified in 3" increments unless approved by Bridge Program Staff.

Table of Girder Spacing							
Clear Roadway Width	Out-Out Width	Number of Girders		Girder Spacing (C-C)		Cantilever	
		Wide Flange	Welded Plate	Wide Flange	Welded Plate	Wide Flange	Welded Plate
26′-0″	29′-4″	4	4	8′-0″	7′-6″	2′-8″	3′-5″
28′-0″	31′-4″	4	4	8′-6″	8′-0″	2′-11″	3′-8″
30′-0″	33′-4″	4	4	9′-3″	8′-6″	2′-9½″	3′-11″
32′-0″	35′-4″	5	4	7′-6″	9′-6″	2′-8″	3′-5″
34′-0″	37′-4″	5	5	8′-0″	7′-6″	2′-8″	3′-8″
36′-0″	39′-4″	5	5	8′-6″	8′-0″	2′-8″	3′-8″
38′-0″	41′-4″	5	5	9′-0″	8′-6″	2′-8″	3′-8″
40′-0″	43′-4″	5	5	9′-6″	9′-0″	2′-8″	3′-8″
42′-0″	45′-4″	6	5	8′-0″	9′-6″	2′-8″	3′-8″

When a very shallow girder depth is required, consideration should be given to minimizing the cantilever length. If possible try to limit the cantilever length to the girder depth.

When vertical clearances require a grade raise, the design engineer should investigate adding a girder line with a smaller section depth.

Steel Girders Sizes

The minimum steel girder depth will be 24" unless approved by Bridge Program Staff.

Minimum web thickness for rolled beam girders shall be ¼".

Girder piece lengths should be kept to around 75'-0" for rolled beam girders W 27 and larger and 65'-0" for rolled beam girders smaller than W 27.

Minimum plate sizes for welded plate girders shall be as follows:

- 5⁄16" plate thickness for all material
- 5⁄16" girder web thickness (in 1⁄16" increments and 1" web depth increments)

¾" x 12" flange (in ⅛" thickness increments up to 1½" with ¼" increments thereafter and 1" width increments)

For bridges crossing roads or railroads, the minimum bottom flange thickness for the section directly over the roadway or tracks shall be 1.5 inches.

The bottom flange width should be kept consistent across the length of the structure.

Welded plate girder piece lengths should be kept around 85'-0" and not over 130'-0". The max section depth should be limited to 90" and the maximum piece weight to 25 tons. There may be special situations such as environmental restrictions, floodplain concerns, or span lengths which require welded plate girders to exceed the above noted guidelines. Approval by Bridge Program Staff is required for exceeding these guidelines.

Field splices shall be used to control the piece lengths. Field splices are commonly located near the point of dead load contraflexure. For girders that are composite for the positive moments only, locate the field splice in the dead load negative moment region.

Plate size changes should only be made at field splice locations unless approved by Bridge Program Staff. Shop welded splices can be considered when the cost saving for each steel plate exceeds $1000/splice.

The width of transverse stiffeners shall be in ½" increments with a minimum width of 4".

The minimum stiffener thickness for welded plate girders shall be ½" or the web thickness, whichever is larger.

The minimum stiffener thickness for rolled beam girders shall be 5⁄16" at intermediate locations and ½" at abutments and bents/piers.

Bent plates used for diaphragms shall have a thickness of ⅜" maximum and legs lengths of 3½" or 4".

Steel Girders Depth to Span Ratios

The girder depth to span ratio will meet the values shown in following table. Project requirements to minimize the needed grade raise or environmental concerns (clear span requirements, minimize wetland or waters of the US impacts, etc.) may necessitate a depth to span ratio below the values shown and may be used with Bridge Program Staff approval.

Girder Type	Preliminary / Preferred Girder Sizing	Minimum
Rolled Beam Girder	0.045	0.040
Welded Plate Girder	0.040	0.035

Steel Girders Live Load Deflection

For LRFD designs, the following live load (LL) deflection limits are to be used:

- For structures carrying only vehicles, the service or unfactored deflection, including impact, should not exceed span length over 800 [L/800]. The deflection should be taken as the larger of:
  - Deflection from design truck alone, or
  - Deflection resulting from 25% of the design truck taken together with the design lane load.

- For structures carrying both vehicles and pedestrians, the service or unfactored deflection, including impact, should not exceed span length over 1000 [L/1000]. The deflection should be taken as the larger of:
  - Deflection from design truck alone, or
  - Deflection resulting from 25% of the design truck taken together with the design lane load.

The deflection values from BRASS-GIRDER(LRFD) will include the live load distribution factor which takes into account girder stiffness, number of lanes, and number of beams. The value from BRASS should be used for the live load deflection check, no modification will be required. If the deflection from BRASS exceeds the above noted limits and requires a larger girder section to meet the requirements, discuss with Bridge Program Staff prior to changing the girder dimensions.

For LFD design, the deflection provisions of the 17^{th} Edition of the Standard Specification should be used. The deflection from BRASS_GRIDER (Standard) should be corrected to account for the deck stiffness, number of lanes, and number of beams.

Steel Girders Stiffeners

The use of shear stiffeners should be avoided to help reduce fabrication time and costs. If the web thickness required to resist the shear forces is in excess of ⅝", shear stiffeners should be considered. Place stiffeners only where required by design.

Stiffeners shall be placed normal to flanges except on bridge structures with extreme grades where it may be desirable to have the bearing stiffeners placed vertically.

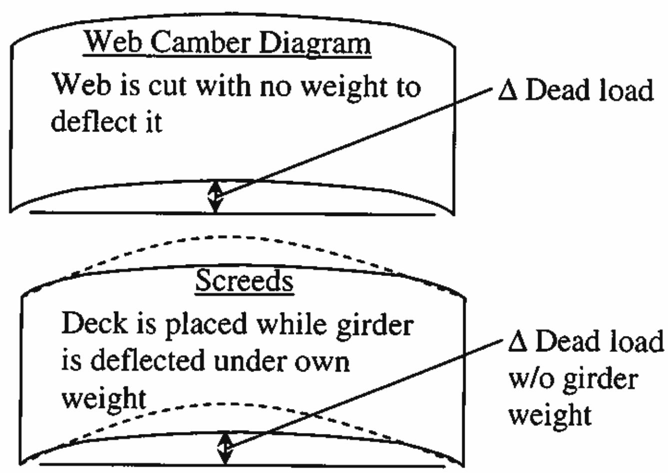
Where possible, webs should be proportioned without the use of longitudinal stiffeners. If longitudinal stiffeners are needed to prevent web buckling, they shall be placed one- fifth ($^1/_5$) of the web depth from the inner surface of the compression flange for a symmetric girder, 2Dc/5 for a non-symmetric girder, or as required by design.

Steel Girders Camber

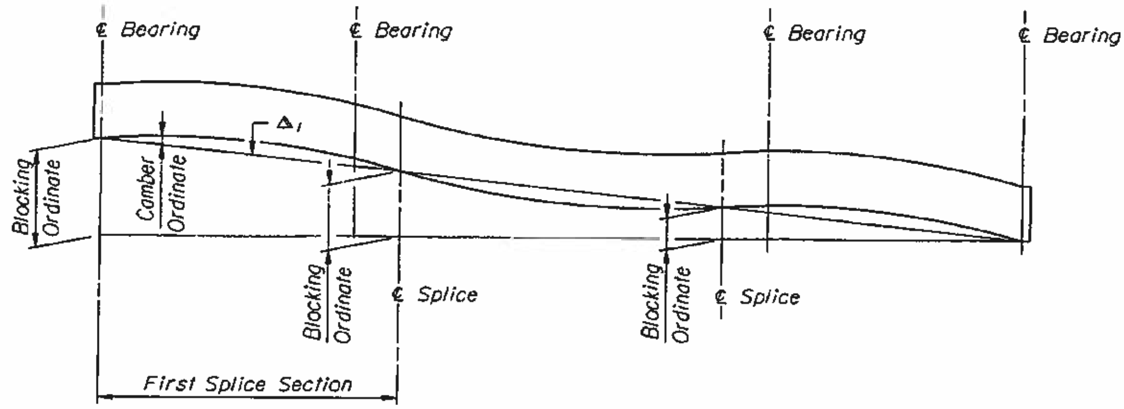
Welded plate girders shall be cambered to compensate for dead load deflection, grade, and/or vertical curvature. The camber is shown in the web cutting diagram. A sufficient number of camber ordinates, usually ten per span, shall be determined.

In most cases camber is not required for rolled beam girders. Heat cambering for rolled beam girders should be avoided due to fabrication cost. If no camber is required for rolled beams, this should be noted in the design.

A blocking diagram shall be developed for rolled beam girders when the slab thickness is less than the design slab thickness or thicker than the design slab thickness by 1" or more.



Camber, Screeds, and Blocking Ordinate Calculations:



1. Determine final grade elevations (FG_{elev}) along girder line
2. Screed elevations, $Screed_{elev} = FG_{elev} + \Delta DL_{w/o\ girder\ weight}$
3. Camber elevation, $Camber_{elev} = FG_{elev} + \Delta DL_{total}$
4. Determine slope (δss) of chord between blocking ordinates

$$\delta_{splice\,section} = \frac{C_{elev\,hss} - C_{elev\,lss}}{L_{ss}}$$

Where: ss = splice section

hss = highest end of splice section

lss = lowest end of splice section

Lss = length of splice section

5. Determine change of grade at point x from lowest end of splice.

$\Delta_{grade} = (\delta_{ss})(Lx)$

Where Lx is the length from the point of interest (x) to lowest end of splice section

6. Determine Grade elevation at point x

$Grade_{elev} = C_{elev\ lss} + \Delta_{grade}$

7. Determine camber ordinate at point x

$\Delta_{xc} = Camber_{elev} - Grade_{elev}$

8. Determine blocking ordinate at high end of splice section

Blocking ordinate = $Grade_{elev\ hss} - Grade_{elev\ lss}$

For rolled beam bridges a slab thickness diagram is used. It represents the actual deck thickness above the top flange of the girder and is based on dead load deflection, grade, and vertical curvature. The values should not exceed the design slab thickness plus 1" minus the top flange thickness, nor should they be less than the design slab thickness minus the top flange thickness. If either situation occurs, a blocking diagram will be required.

1. Determine final grade elevations (FG_{elev}) along girder line
2. Screed elevations, $Screed_{elev} = FG_{elev} + \Delta DL_{total}$
3. Slab thickness = design slab thickness (typically 8") + ΔDL_{total}

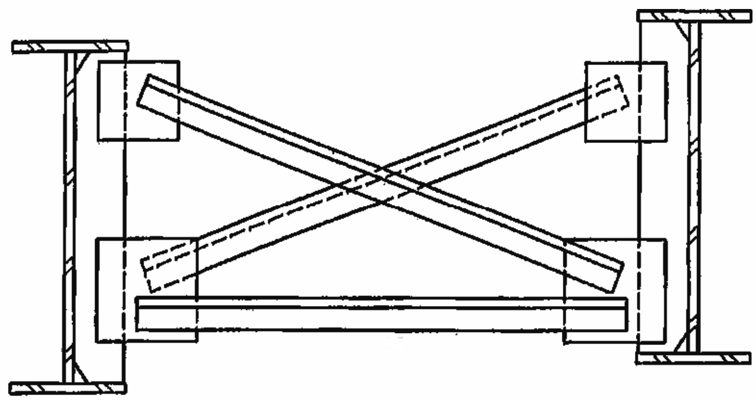
Steel Girders Bracing

A framing plan (stick diagram defining the location and orientation of stiffeners, bottom lateral bracing, cross frames, diaphragms, splices, and substructures in relationship to the girders) shall be shown in the design.

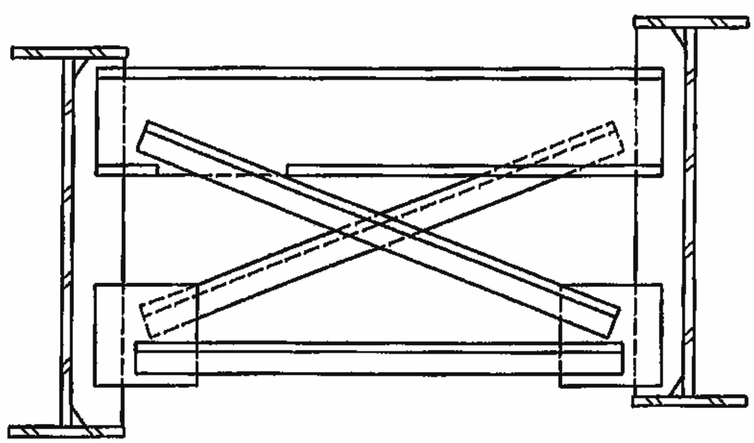
Cross frames and diaphragms are secondary elements, except for curved girders and some seismic designs. They are used to distribute loads laterally and help with girder erection and construction. Spans shall be provided with cross frames or diaphragms at each non-embedded end and at intermediate locations with spacing not to exceed 25'-0" for welded plate girders and 15'-0" for rolled beam girders.

Cross frames and diaphragms are to be placed normal to girders unless the bridge skew is 20 degrees or less, in which case they shall be placed parallel with the substructure. Cross frames and diaphragms shall be in a continuous line across the girders when possible. The design engineer shall ensure that the cross frames and diaphragms shall not interfere with the installation and operation of the anchor bolts at bent/pier locations. Use of angles with equal legs is preferred for weathering steel bridges due to availability.

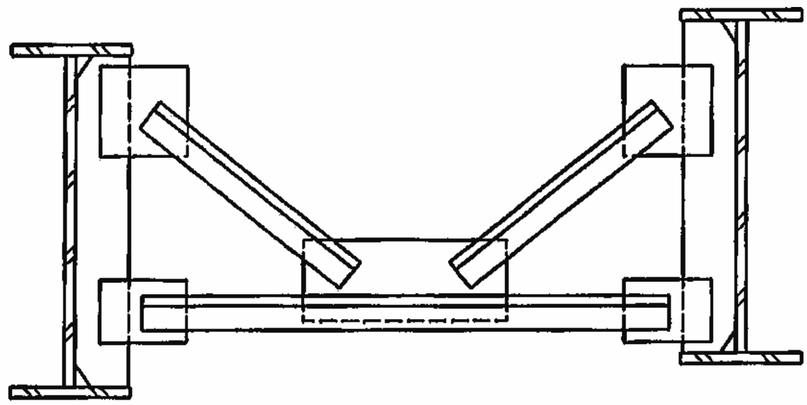
The X Type cross frame is the preferred intermediate type, generally composed of angles and gusset plates welded or field bolted into place.



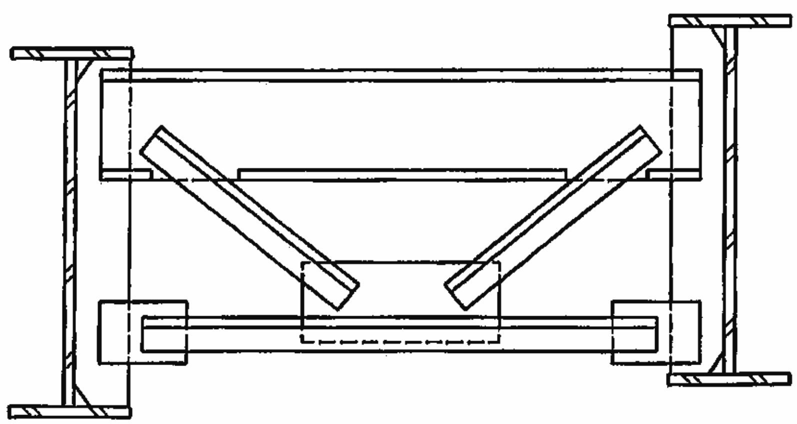
This version of the X Type cross frame is used at bearing locations. The top horizontal member is usually a wide flange shape at slab supports or an angle when the top horizontal member is not loaded vertically.



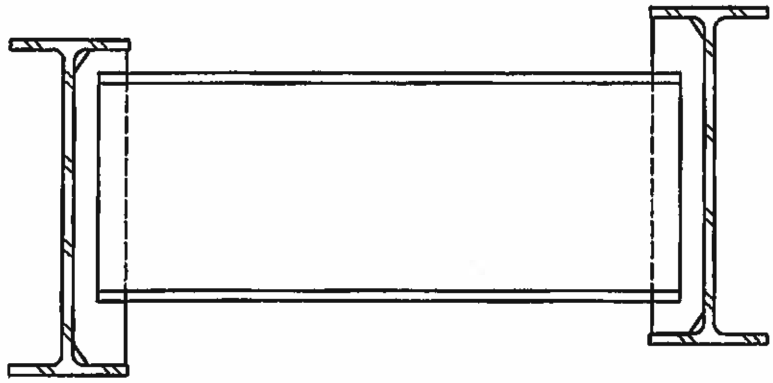
The K Type cross frame should be used when the angle between the diagonal and horizontal members in the X Type cross frame is less than 25 degrees.



This version of the K Type cross frame is used at bearing locations. The top horizontal member is usually a wide flange shape at slab supports or an angle when the top member is not loaded vertically.



Diaphragms are used with shallow girders with web depths less than 40". Diaphragms shall be bent plates or channels.



Bottom lateral bracing is primarily used to resist lateral forces due to wind or live loading. Bottom lateral bracing should be considered for spans greater than or equal to 125'-0". Bracing may be waived with the approval of the Bridge Program Staff. All bracing shall be placed in the exterior bays between the cross frames as close to the bottom flange as possible.

Wind loading for the constructability and girder design check shall follow the requirements of Article 3.8 of the LRFD specifications. Reduction of the wind load shall only be done with approval of Bridge Program Staff.

Steel Girders Connections

Fillet welds are used for the majority of welding of girders and their members. Unless a larger size is specified in the design, the weld size is determined by the thicker of the two parts being joined, except that the weld size need not exceed the thickness of the thinner part being joined. Fillet welds on all stiffeners and cross frame members shall be held back ¼" from the ends of the stiffeners and members.

Minimum Size of Fillet Welds	
Base Metal Thickness of Thicker Part Joined (T)	Minimum Size of Fillet Weld
T ≤ ¾"	¼"
T > ¾"	$^{5}/_{16}$"

High strength bolts should be used for all connections unless approved by Bridge Program Staff. High strength bolts shall be ⅞" in diameter. If non-standard bolt size, bolt pitch, edge distance, and/or hole sizes are used, they shall be shown in the design and details.

Standard bolt patterns to be used in the web field splices shall be 3" x 3" for rolled beam girders and 4" x 4" for most welded plate girders, except when another pattern is required by design. The horizontal bolt spacing for flange splices is 3".

The table below shall be used for the length of weld and/or number of bolts required for connection of various cross frame and bottom lateral bracing members, unless otherwise required by the design.

Table of Connections		
□Member	*Length of ¼" Fillet Weld (in)	Number of ⅞" ϕ HS Bolts
WT 4 x 8.5	14	4
WT 4 x 10	16	4
WT 4 x 12	20	4
WT 5 x 10.5	16	4
WT 5 x 12.5	20	5
L 3 x 2½ x 5/16	8	2
L 3 x 3 x 5/16	8	2
L 3½ x 3 x 5/16	10	2
L 3½ x 3½ x 5/16	10	2
L 4 x 3½ x 5/16	10	2
L 4 x 4 x 5/16	12	2
L 5 x 5 x 5/16	14	3
L 6 x 4 x 5/16	16	3
L 6 x 6 x ⅜	20	5

* Denotes entire weld length. If connection is welded on both sides each weld is half this length.

□ Use of angles with equal legs is preferred for weathering steel bridges due to availability

3" bolt spacing shall be used for channels and bent plate diaphragms. The number of bolts should be maximized to fit within the section and based on the dimensions shown in the Bridge Applications Manual.

Concrete Girders Materials

Concrete for cast-in-place (CIP) girders shall meet the requirements of Class B concrete as noted in the *Standard Specifications for Road and Bridge Construction.* If a CIP girder bridge is being widened, the concrete strength (f'_c) should match the design strength used for the existing bridge.

For precast – prestressed girders the following minimum concrete strengths shall be used:

$f'_c = 5000$ psi
$f'_{ci} = 4000$ psi

Prestressing steel shall have a minimum strength (f'_s) of 270,000 psi

Main reinforcing steel shall use a minimum strength (f_y) of 60,000 psi.

Concrete Girders General Design

Cast-in-place (CIP) girders should only be used for widening bridges that used this girder type in the original construction due to the form and false work needed.

For structures that use prestressed-precast concrete girders, multiple span bridges can be either a series of simple spans or continuous spans. A list of commonly used types of prestressed-precast concrete girder sections can be found in the *PCI Precast Prestressed Concrete Bridge Design Manual.*

In general, multiple span bridges utilizing a cast-in-place concrete deck for composite action will be designed and detailed using simple span analysis for stage one dead loads and continuous span analysis for superimposed dead loads and live loads. Other multiple span girder types without cast-in-place decks, such as bulb T, twin T, and tri-deck, will most likely be designed and detailed using simple span analysis for all load stages.

Currently, for continuous structures typically used by the Bridge Program, the precast fabricator will design the girder using a simple span analysis for all load stages. For most cases this method is conservative for moment design; however it may not be conservative for shear design. The engineer shall ensure that adequate shear and negative moment capacity over the interior supports is provided considering the continuous span case.

Selection of the girder sections should be based on design graphs, charts, and literature produced by the girder fabricators best located geographically to get the contract. Currently, these references are based on HS20 and HS25 live loads. Some guidelines for designing are as follows:

> Span lengths for I-girder sections are adequate for spans up to 140'-0".
>
> Bulb T sections are adequate for the spans from 50'-0" to 120'-0".
>
> Tri-deck sections are adequate for spans up to 65'-0".

The precast fabricators supplying girders for WYDOT generally use the LEAP program for design. The Bridge Program usually checks the input for the program and results at critical locations such as the transfer point, harp point, midspan, and lift loop locations. The BRASS Girder program should be used to check the design and to determine the load rating for the fabricator's design.

Allowable Stresses in Prestressed Members: Under service limit state the tensile stresses in the precompressed tensile zone shall be limited to zero. This prevents cracking of the concrete during the service life of the structure and provides additional stress and strength capacity for overloads. Allowable concrete stresses for the service and fatigue limit states are shown in the following table

Condition	Stress	Location	Allowable Stress
Temporary Stress at Transfer and at Lifting from Casting Bed	Tensile	In areas other than the precompressed tensile zone and without bonded reinforcement	$0.0948\sqrt{f'_{ci}} \leq 0.2$ (ksi)
		In areas with bonded reinforcement sufficient to resist tensile force in the concrete	$0.19\sqrt{f'_{ci}}$ (ksi)
	Compressive	All locations	$0.65f'_{ci}$ (ksi)
Temporary Stress at Shipping and Erection	Tensile	In areas other than the Precompressed tensile zone and without bonded reinforcement	$0.0948\sqrt{f'_{ci}}$ (ksi)
		In areas other than the precompressed tensile zone and with bonded reinforcement, plumb girder with impact	$0.19\sqrt{f'_{ci}}$ (ksi)
		In areas other than the precompressed tensile zone and with bonded reinforcement, inclined girder without impact	$0.24\sqrt{f'_{ci}}$ (ksi)
		In areas other than the precompressed tensile zone and with bonded reinforcement, after temporary top strand detensioning	$0.19\sqrt{f'_{ci}}$ (ksi)
	Compressive	All locations	$0.65f'_{ci}$ (ksi)
Final Stresses at Service Load	Tensile	Precompressed tensile zone	0.0
	Compressive	Effective prestress and permanent loads	$0.45\sqrt{f'_{ci}}$ (ksi)
		Effective prestress, permanent loads and transient loads	$0.60\sqrt{f'_{ci}}$ (ksi)
Final Stresses at Fatigue Load	Compressive	Fatigue 1 Load Combination plus one-half effective prestress and permanent loads per AASHTO LRFD 5.5.3.1	$0.40\sqrt{f'_{ci}}$ (ksi)

Bearings are provided at each intersection with the substructure. The most common types of bearing used are Elastomeric Bearing Devices and ½" Elastomeric Bearing Pads. Elastomeric bearing devices transfer the load from the superstructure to the substructure and allow the superstructure to move due to the thermal expansion or contraction, along with live / dead load rotations. A ½" elastomeric bearing pad is used when the superstructure is integral with the substructure to allow for initial girder rotation and provide a smooth bearing surface for the girder.

For each steel reinforced elastomeric bearing device, include in the plans the unfactored design dead and live loads.

Anchor bolts shall be used to securely anchor the girders to the substructure when the girders are not embedded. Anchor bolts shall be threaded or swedged to secure a satisfactory grip upon the material used to embed them in the holes. The following are the minimum requirements for each bearing.

Table of Anchor Bolts			
Span Length	Number of Bolts	Bolt Size (Diameter)	Distance Set into Masonry
50'-0" or less	2	1"	10"
51'-0" to 100'-0"	2	1¼"	12"
101'-0" to 150'-0"	2	1½"	15"
150'-0" or more	4	1½"	15"

Note: Use longest span immediately adjacent to bearing. Seismic design may dictate a larger diameter bolt size or additional anchor bolts.

Anchor bolt holes shall be square formed holes or round drilled holes as shown in the following table. The minimum clear distance from a drilled hole to the face of any reinforcing steel shall be 1".

Table of Anchor Bolts		
Anchor Bolt (Diameter)	Square Formed Hole	Drilled Hole (Diameter)
1"	1¾"	1½"
1¼"	2"	1¾"
1½"	2¼"	2"

The use of beveled sole plates should be considered when the bridge grade exceeds 0.5%. Bevel plates shall be placed between the pad and the girder flange. The minimum thickness of the bevel plate shall be ¾" and increase in size in ⅛" increments at the thickest part of the plate. Plate thicknesses shall be detailed to $^{1}/_{16}$" at the beveled end.

For integral cap type abutments, use an unreinforced pad (½" thick) x (bottom flange width) x (the flange length in contact with the abutment cap). Clip the pad flush with the front of the abutment cap on skewed bridges. If a beveled sole plate is required, use the same plan size as the pad. Clipping of the girder flanges may be needed to keep the girder ends 6" minimum clear from the rear face of the abutment. Dimension the pad and sole plate to the nearest $^{1}/_{16}$".

Elastomeric Bearing Design

For pile bents with a steel bent cap, the minimum pad width shall be the bottom flange width plus 10". Shims shall be placed on top of the bearing pads to account for the roadway crown. The minimum shim dimensions shall be the bottom flange width x sole plate length. Use a base plate underneath the pad, field welded to the bent cap. The base plate shall be the same plan size as the sole plate. design of steel reinforced elastomeric bearings will be accomplished using Method A of the LRFD design specification. The use of Method B requires approval by Bridge Program Staff.

Loads and Rotations:

The use of the concurrent reaction with the maximum rotation from the HL-93 truck or tandem and lane combination should be used for the rotation check in Article 14.7.6.3.5. BRASS-GIRDER (LRFD) will provide the concurrent actions at the bearing locations. The truck-train reactions at intermediate supports should be used for the compressive checks in Articles 14.7.6.3.2 and 14.7.6.3.3 only.

The specification, Article 14.4.2.1, calls for the use of a 0.005 rad allowance for uncertainties. This value, when added to the rotations from grade, live load, and dead loads, creates a rotation that is very difficult to design for. The WYDOT Standard Specifications for Road and Bridge Construction does not show any tolerances for the forming of the level area where the bearing pads are to be placed. Discussions with field personnel indicate that they expect the bearing area to be level and at the elevations shown in the plans. If problems do occur during construction, the Supplemental Specification for Bridge Bearing Correction is to be used to correct any gaps between the bearing pad and the concrete surface. When designing bearings, a longitudinal rotation of 0.003 radians should be used for uncertainties. No uncertainties should be used in the transverse direction since the girders will always be braced in the transverse direction by the cross frames.

Pad and Sole Plate Geometry:

Plan dimensions of bearing pads will be to the nearest whole inch. Dimension pad thickness in ¼" increments. Place steel reinforcing sheets at equal spaces in the pad with the top, bottom, and sides of reinforcing steel sheets having a minimum cover of ⅛" of elastomer. Use a minimum reinforcing steel thickness of 11 gage, and use only gage to dimension the reinforcement thickness. Use a minimum of two reinforcing sheets per pad.

Use the following minimum dimensions for pad and sole plates:

- Bearing pads
  - Width (transverse to girder) = Bottom girder flange width plus 1"
  - Length (parallel to girder) = 6"

- Sole plates - Placed between the girder and pad
  - Thickness = ¾"
  - Width = Bearing pad width plus 8"
    - The clear distance between the pad and the slot in the sole plate should be 1" minimum.
  - Length = Bearing pad length plus 3"

Design the sole plate thickness for moment at the edge of the girder flange and weld sole plate to the girder flange.

The following equations should be used to determine slot size for sole plates used with elastomeric bearings. Some situations might require longer slots for anticipated temperature movements or bridge construction tolerances. Slots in PTFE bearings are discouraged to keep sliding surfaces free of debris.

$$L = \phi + 2\Delta + \tfrac{1}{2}''$$
$$W = \phi + \tfrac{1}{4}''$$

Where: Δ = temperature movement
ϕ = bolt diameter
L = length of slot (rounded up to nearest ¼")
W = width of slot (rounded up to nearest ¼")

Keeper System:

All bearing pads will be designed without holes in the pad for the anchor bolts. All bearing systems will need keeper bars incorporated into the details, see the Bridge Applications Manual.

If a keeper system is required by design, it will consists of a sole plate, elastomeric bearing, masonry plate, keeper bars, and preformed fabric bearing pad. The top 3/8" keeper bars shall be slotted, 4" wide bars to maintain the appropriate edge distance from the slots. The bottom 3/8" keeper bars shall be shop (stitch) welded to the masonry plate for the entire length of the bars. Portions of the elastomeric bearing pad thickness adjacent to the 3/8" keeper bars shall not be included in the design thickness of the pad.

If keepers are required by design, they should be in direct contact with the pad; otherwise the portions adjacent to the keepers should be included in design

Clearance to Anchor Bolts:

The standard detail for elastomeric bearings is to keep the anchor bolts outside of the elastomeric pad. The Bridge Applications Manual (Section 4.8) has a detail that shows the minimum edge distance to the masonry or sole plate from the edge of the concrete seat to be 4". The clearance from the edge of the concrete seat to the edge of the anchor bolt should be 6" minimum. At least one shear stirrup is to be placed between the anchor bolt and the end of the seat.

Wind Loads

The application of the wind load should follow Article 4.6.2.7 of the LRFD Specifications with the following exception. The distribution of the wind load can be determined by modeling the bridge as uniformly loaded on all spans and determining the wind load at the points of interest or the following equations can be used:

For positive moment areas $M_w = \frac{WL_s^2}{20}$

For negative moment areas $M_w = \frac{WL_s^2}{10}$

Where: W = factored wind force (klf)
L_s = Length of span (ft) (use longer span for negative moment calculations)