Design for Constructability Guidelines

S2.1 Steel Bridge Fabrication Guide Specification

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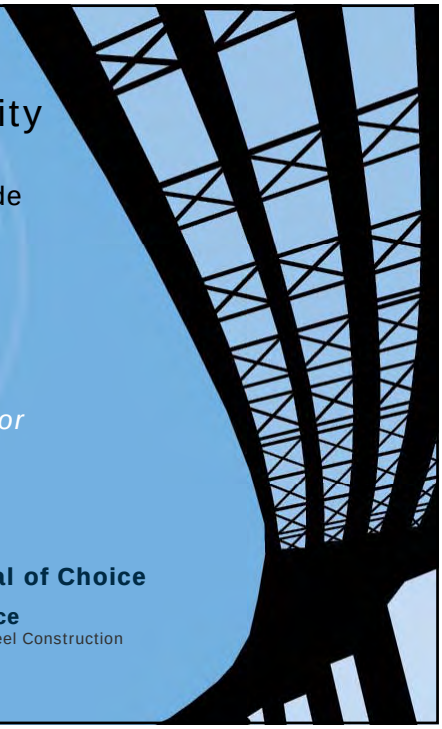


Steel: The Bridge Material of Choice

National Steel Bridge Alliance
A division of the American Institute of Steel Construction
www.steelbridges.org

Document and Group Background

Brief Background

- AASHTO/NSBA Steel Bridge Collaboration
- Development of Guidelines
- Final Consensus

Chapters

- Design
- Girder Design
- Boxes
- Bolts
- Corrosion Protection
- Other

Section 1

Design

Design

- Rolled Beam vs. Plate Girder
- Girder Spacing
- Minimum Thicknesses
- Material Availability
- Flange Sizing
- Differential Deflections
- Bearings

Design

- Rolled Beam vs. Plate Girder
  - Rolled beam generally more economical
  - Availability dependent on rolling schedules.
  - Except with hard curve or camber
  - Allow plate girder alternate (show on bid documents)

Nucor-Yamato Proposed Roll/Cast Schedule * ISO 9001:2008 Registered * July 27, 2011

Week Beginning		24 Jul	31 Jul	7 Aug	14 Aug	21 Aug	28 Aug	4 Sep	11 Sep	
NYS Fiscal Month		July	Aug	Aug	Aug	Aug	Sep	Sep	Sep	
NYS Fiscal Week		30	31	32	33	34	35	36	37	
Wide Flange Sections	Prod. Mill	roll wk - cast date	roll wk - cast date	roll wk - cast date	roll wk - cast date	roll wk - cast date	roll wk - cast date	roll wk - cast date	roll wk - cast date	Approximate Next Roll Week
W44x16x230-335	2	33 Cast							shutdown	10/16-10/23 Wks
W40x16x199x431	2	33 Cast							shutdown	10/16-10/23 Wks
W40x12x149-327	2	33 Cast							shutdown	10/23-10/30 Wks
W36x16.5x231-441	2	33 Cast	33 Cast				35 O		shutdown	10/23-10/30 Wks
W36x12x135-256	2		33 Cast		34 I 8/2		35 O		shutdown	10/2-10/9 Wks

Design

- Girder Spacing
  - Wider is more economical.
  - Fewer girders means fewer linear feet to detail, fabricate, paint, transport, erect, inspect and maintain.
  - Fewer diaphragms, cross-frames, bearings and bolts.
  - Possibly MORE pounds per length of girder; however FEWER dollars overall.
  - Reduced fabrication and erection time.

Design

- Girder Spacing
  - Use 10’ to 11’ with spans less than 140’.
  - Use 11’ to 14’ with spans greater than 140’.
  - Cost of thicker deck to accommodate wider spacing.
    - Thicker deck may increase life.
    - More dead load per girder may reduce vibration.
  - Consider future re-decking operations during preliminary design.

Design

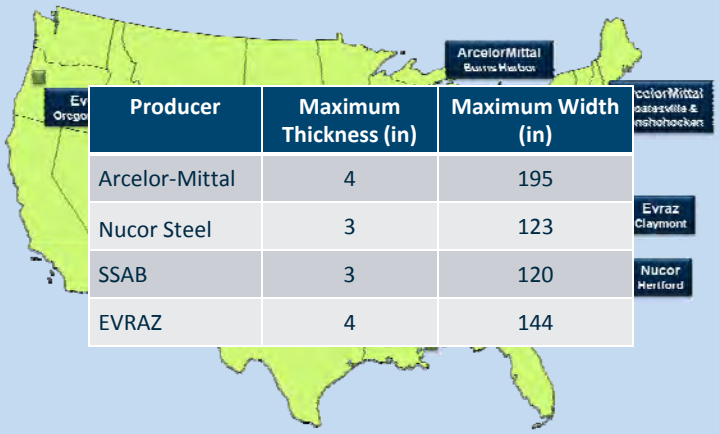
Girder Spacing

Design

- Minimum Thicknesses
  - Stiffeners and connection plates typically 7/16" minimum with 1/2" preferred.
  - Plate girder webs typically 7/16" minimum with 1/2" preferred.
  - Plate girder flanges 3/4" minimum.

Design

•Plate Availability



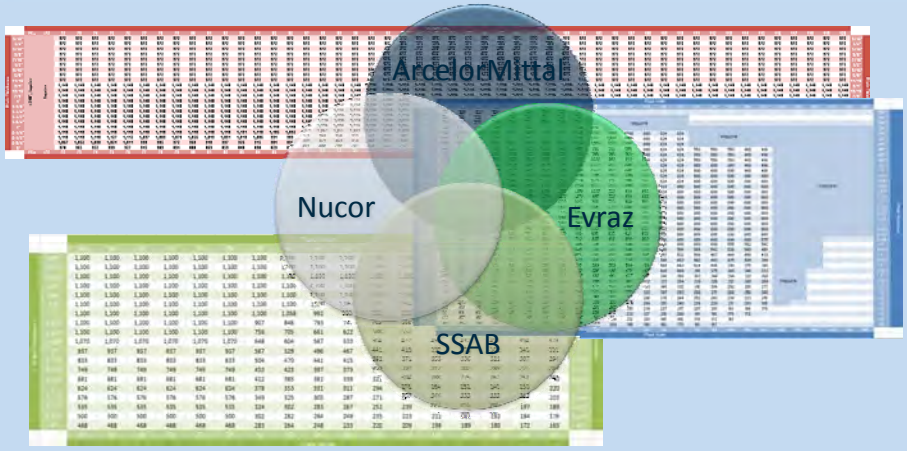
Producer	Maximum Thickness (in)	Maximum Width (in)
Arcelor-Mittal	4	195
Nucor Steel	3	123
SSAB	3	120
EVRAZ	4	144

Design

- Plate size availability and preferences
  - Thickness
    - 1/8” for plate up to 2 1/2” thick
    - 1/4” for plate over 2 1/2” thick
  - Width
    - Fabricators prefer 72” and 96” widths.
    - Cost increases with width

Mill Plate Availability Charts

- Rationalize all mill plate tables



Mill Plate Availability Charts

- Rationalize all mill plate tables

Plate Availability Chart: Minimum Composite									
	Plate Width								
Plate Thickness	72"	78"	84"	90"	96"	102"	108"	114"	120"
3/8"	972	972	972	972	972	800	972	972	750
1/2"	972	972	972	972	972	972	972	680	680
9/16"	972	972	972	972	972	972	972	680	680
5/8"	972	972	972	972	972	960	960	680	680
3/4"	1,100	1,100	1,100	1,100	1,100	1,030	980	680	680
7/8"	1,100	1,100	1,100	1,100	1,100	1,030	980	680	680
1"	1,100	1,100	1,100	1,058	992	933	882	680	680
1-1/4"	1,100	994	907	846	793	747	705	668	635
1-1/2"	1,077	828	756	705	661	622	588	557	529
1-3/4"	924	710	648	604	567	533	504	477	453
2"	808	621	567	529	496	467	441	418	397
2-1/4"	718	552	504	470	441	415	392	371	353
2-1/2"	646	110	453	423	397	373	353	334	317
2-3/4"	588	452	412	385	361	339	321	304	288
3"	539	414	378	353	331	311	294	278	264

* A709-50 and A709-50W (Non-FC) Availability only.

Design

- Wide Flange Beam Availability
  - Nucor Yamato: to 44in deep
  - Chaparral: to 36in deep
  - Steel Dynamics: to 36in deep
  - Maximum length typically 120ft (130ft in some cases).
  - ASTM A992; ASTM A709, Gr. 50S
    - Minimum Yield = 50 ksi
    - No HPS

Design

- Plate girder flange sizing best practices
  - No more than 2 shop slices within shipping piece.
  - Minimum thickness increment of 1/8" (to 2 ½" thick) and 1/4" thereafter.
  - Maximum difference between adjacent plates; thinner piece at least 1/2 of thicker.
  - Extend thicker material when material cost saved is less than labor cost for shop splice.

Design

- Flange Sizing: When to change area?

Multiply weight savings/inch x flange width (length of butt weld)

Thinner Plate at Splice (inches)	Thicker Plate at Splice (inches)						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0
1.0	70	70	70				
1.5		80	80	80	80		
2.0			90	90	90	70	70
2.5				100	100	80	80
3.0					110	90	90
3.5						110	110
4.0							130

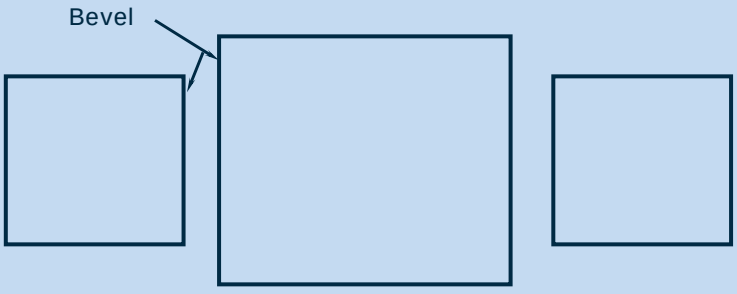
* Weight Saving Factor Per Inch of Plate Width for ASTM A709-Gr 50 Non-Fracture Critical Flanges Requiring Zone 1 CVN Testing

Design

- Plate girder flange sizing best practices
  - Keep widths constant across shipping piece.
  - Change cross section area by changing the thickness.

Design

- Flange Sizing - change width

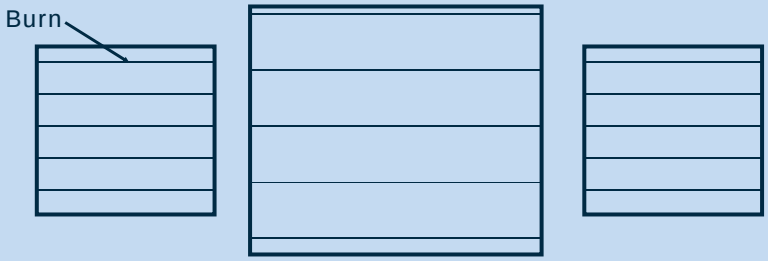


Fabricate 4 Flange Assemblies

Step 1: Bevel (4) Plate Edges

Design

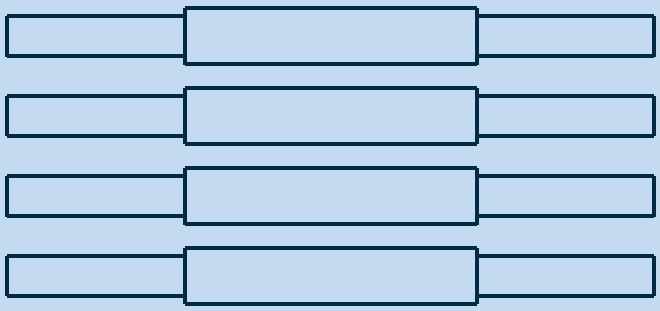
- Flange Sizing - change width



Step 2: Burn 12 Pieces From 3 Plates

Design

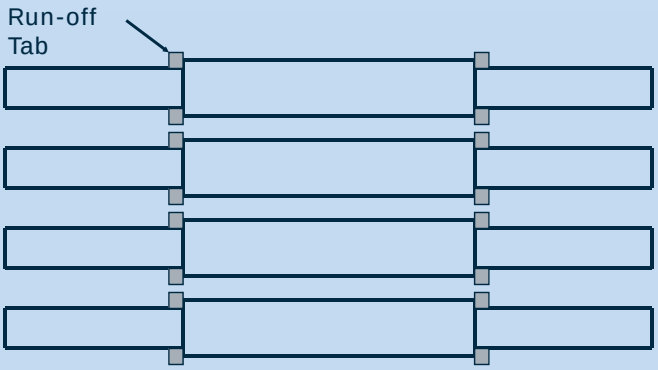
- Flange Sizing - change width



Step 3: Fit up and tack weld 4 flange assemblies

Design

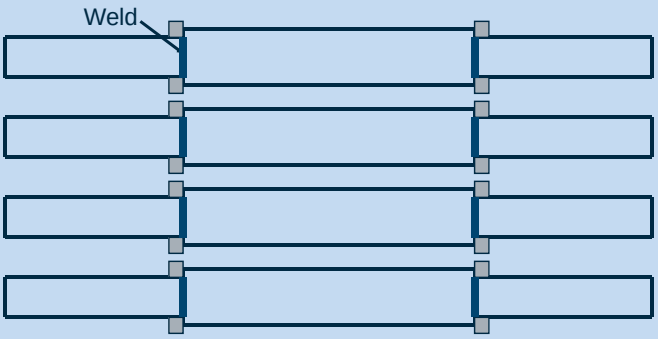
- Flange Sizing - change width



Step 4: Attach 16 run-off tabs

Design

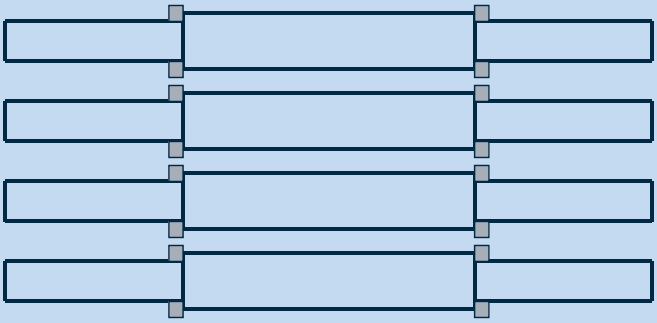
- Flange Sizing - change width



Step 5: Weld and grind 8 splices

Design

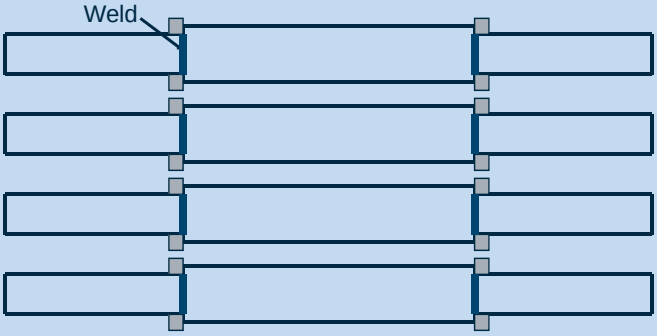
- Flange Sizing - change width



Step 6: Turn over 4 flange assemblies

Design

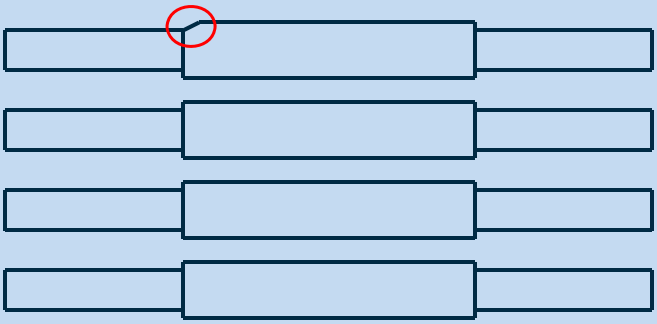
- Flange Sizing - change width



Step 7: Back gouge, weld and grind 8 butt joints

Design

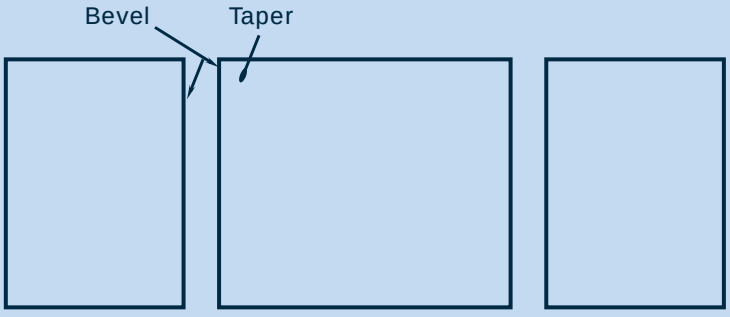
- Flange Sizing - change width



Step 8: Remove and grind 16 run-off tabs, taper wider plates

Design

- Flange Sizing - change thickness



Change Thickness

Step 1: Bevel (4) and Taper (2) Plate Edges

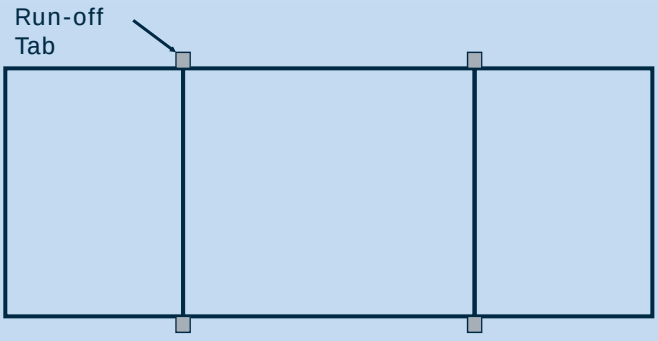
Design

- Flange Sizing - change thickness

Step 2: Fit up and tack weld 3 plates

Design

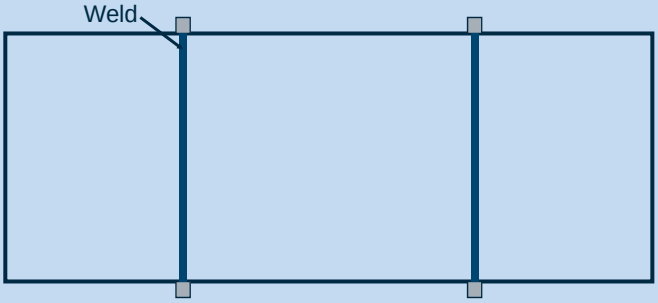
- Flange Sizing - change thickness



Step 3: Attach 4 run-off tabs

Design

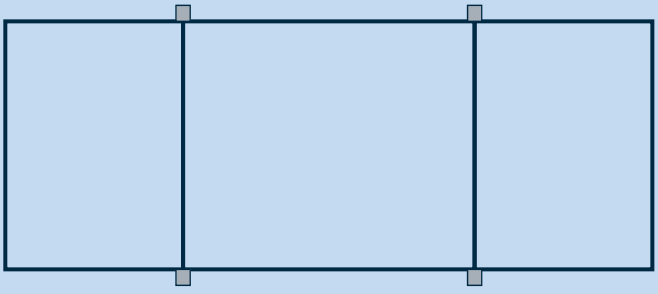
- Flange Sizing - change thickness



Step 4: Weld and grind 2 splices

Design

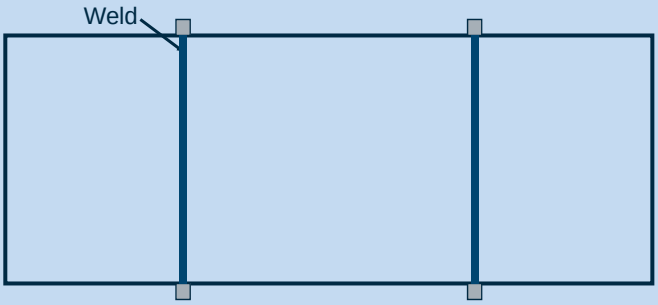
- Flange Sizing - change thickness



Step 5: Turn over 1 piece

Design

- Flange Sizing - change thickness



Step 6: Back gouge, weld and grind 2 butt welds

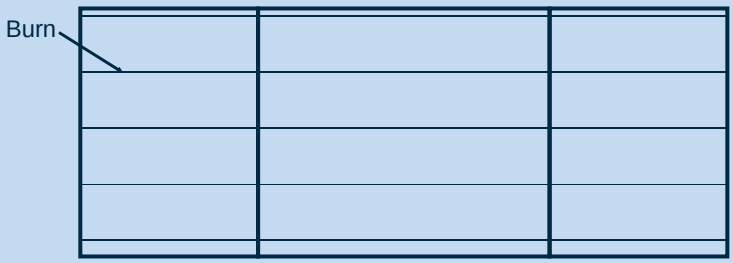
Design

- Flange Sizing - change thickness

Step 7: Remove and grind 4 run-off tabs

Design

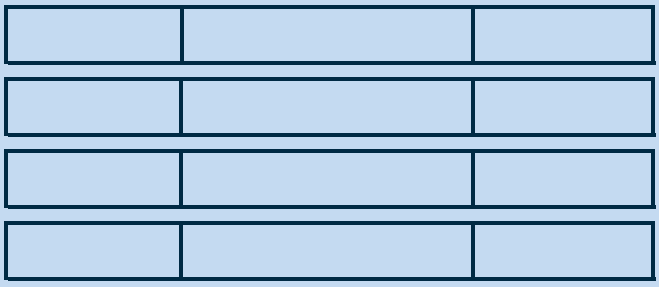
- Flange Sizing - change thickness



Step 8: Burn 4 flanges from 1 assembly

Design

- Flange Sizing - change thickness



Step 8: Burn 4 flanges from 1 assembly

Design

- Flange Sizing
  - Width transitions increase labor for flange assemblies up to 35%
  - If you must change flange width, do so at bolted field splice (do not clip corners of top flanges).
  - Allow fabricators to eliminate splices within a shipping piece by carrying thicker material through to next designed splice location.

Design

- Flange Sizing

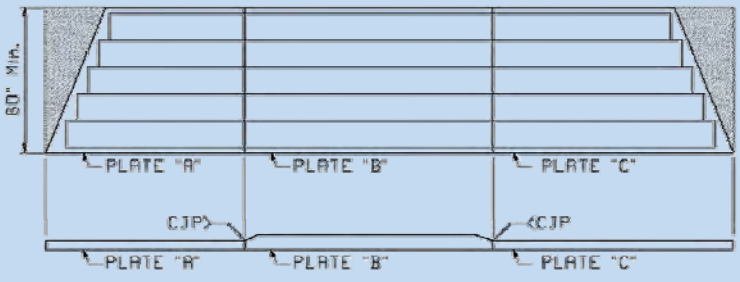


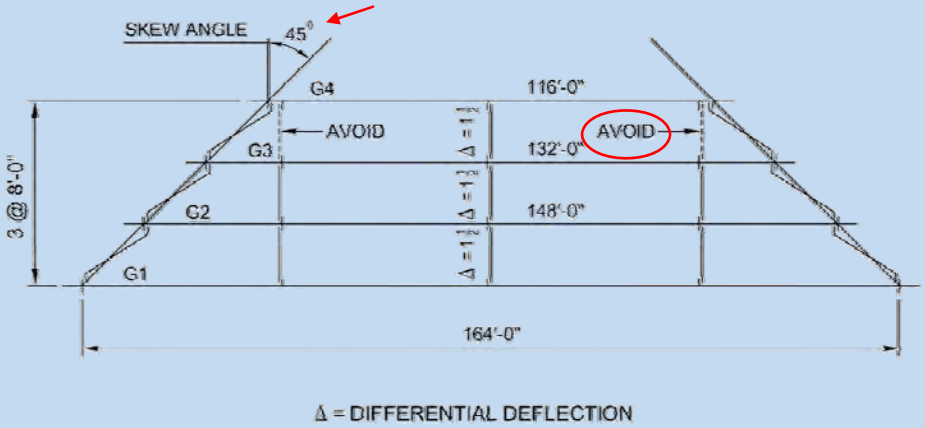
Figure 1.5.2A

Design

- Differential Dead Load Deflections
  - Phased construction
    - If possible, omit cross-frames between phases.
    - Otherwise, single angle top & bottom strut (w/ 1 bolt)
  - Curved girders
    - 'beyond the scope'
  - Skewed girders

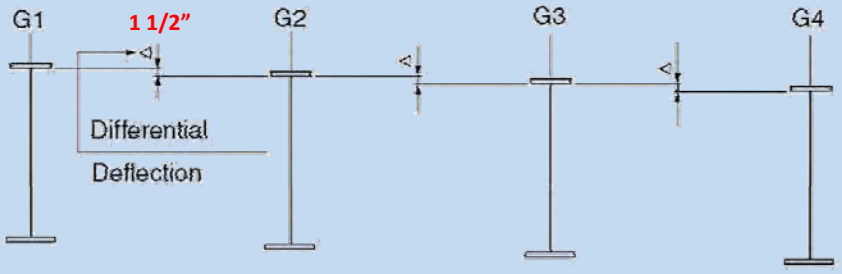
Design

- Skewed Girders



Design

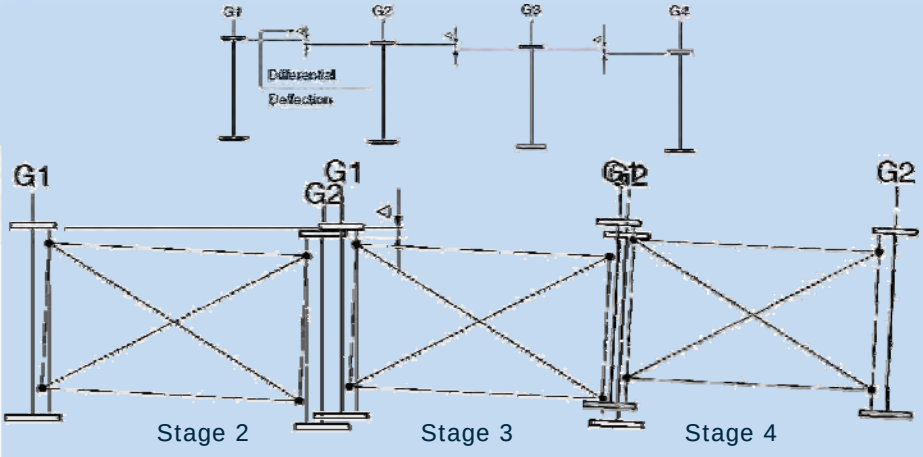
- Skewed Girders



Stage 1

Design: Skewed Girders

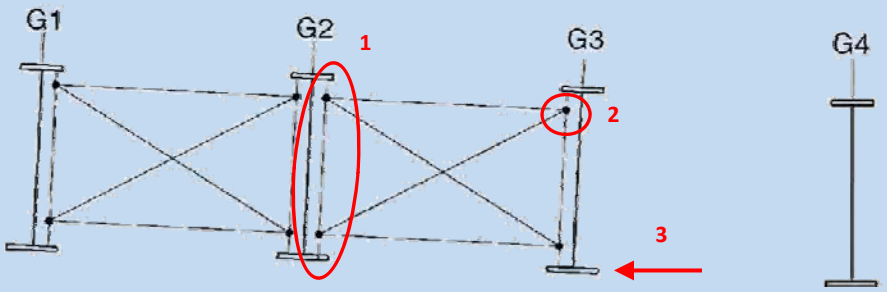
- Skewed Girders



Stage 2 Stage 3 Stage 4

Design

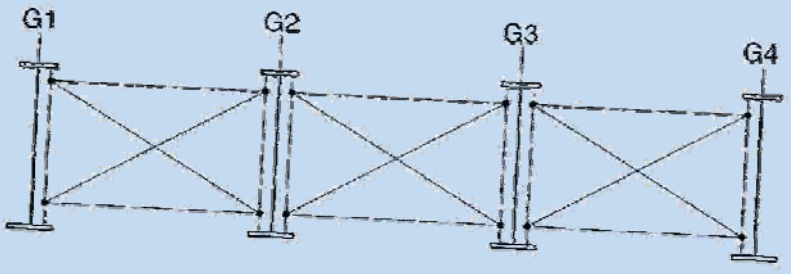
- Skewed Girders



Stage 5

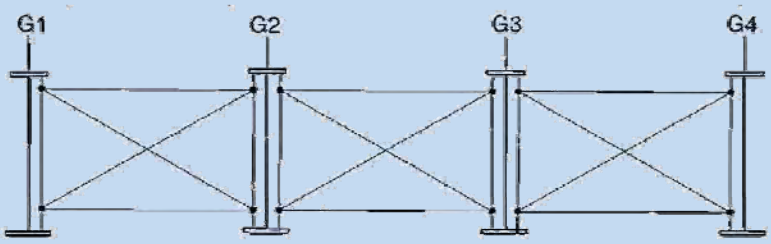
Design

- Skewed Girders



Stage 6

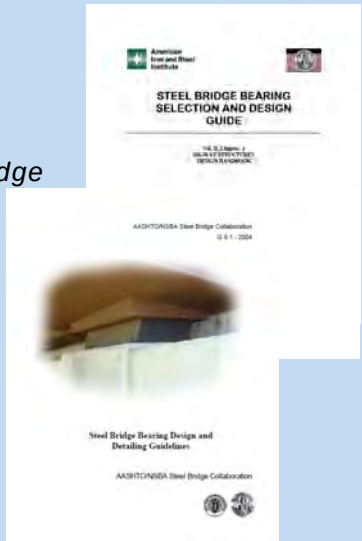
Design: Skewed Girders



Stage 7

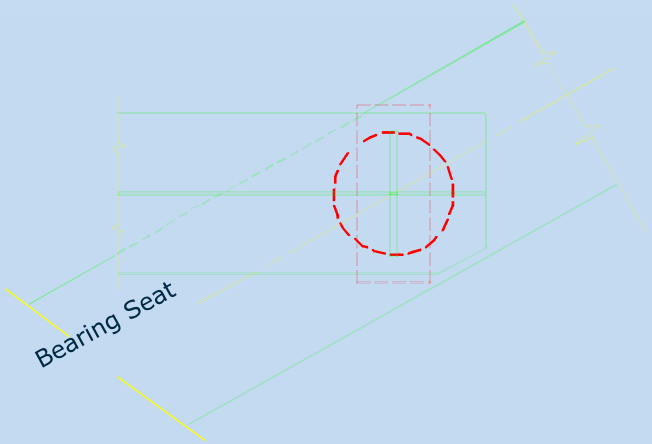
Design: Skewed Girders

- Bearings
  - Use elastomeric when possible.
  - Use pot bearing next.
  - See Collaboration G9.1: *Steel Bridge Bearing Design and Detailing Guidelines*
  - See Highway Structures Design Handbook: *Steel Bridge Bearing Selection and Design Guide.*



Design

- Skewed Girders: Use round bearings



Design

- Bearing Costs
  - Elastomeric - approximately $225 ea
  - Bronze Rocker - approximately $600 ea
  - Pot Bearing - approximately $800 ea
  - Spherical Bearing - approximately $1200 ea
  - Built-Up Rocker - used mostly in RR structures - approximately $1.50/lb

Girders

Design: Girders

- Bearing Stiffeners, Box Girder Bearing Diaphragms, Connection & Intermediate Stiffeners.
- Welding and Related Details.
- General Details.
- Longitudinal Web Field Splices.

Design: Girders

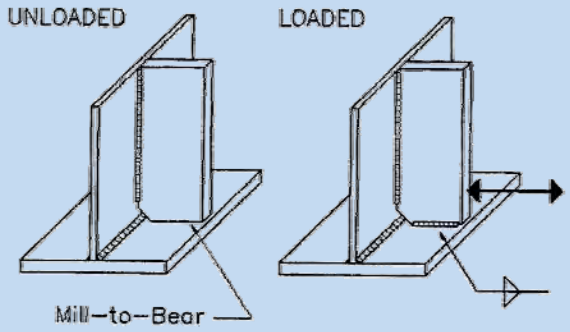
- Bearing Stiffeners
  - Fabricated normal to top flange.
  - Fabricated vertical (plumb) under full dead load (DL) - effect on design is minimal.
- Connection/Intermediate stiffeners
  - Fabricate normal to top flange.

Design: Girders

- Bearing Stiffener Attachment
  - Mill bear fit on bottom flange
    - Fillet weld if transversely loaded.
    - No full penetration welds to reduce deformations in bottom flange.
  - AWS D1.5 specifies tolerances for fit between underside of bottom flange and bearing sole plate (projected area of bearing stiffeners and web).

Design: Girders

- Bearing Stiffeners
- Minimum Spacing between Stiffeners
  - 7” – 10” or 1 1/2 times stiffener plate width

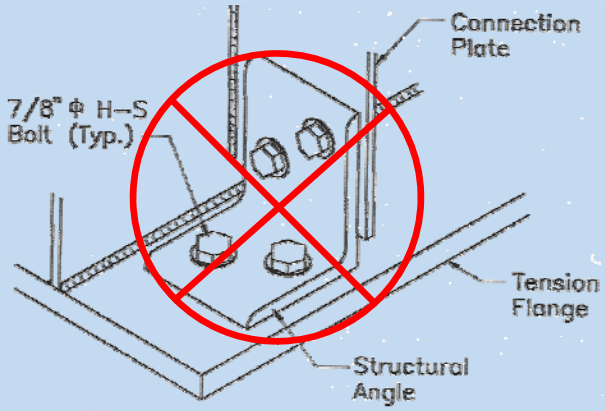


Design: Girders

- Connection Stiffener Attachment
  - Attach to top and bottom flanges
  - Welds to tension flanges ARE ALLOWED if stress in the flange is less than the allowable fatigue stress for the type of weld.
  - Good placement of connection plates should eliminate need for any tab plates.
  - If needed, use tab plates only at the specific location, not at all connection plates.

Design: Girders

- Connection Stiffener Attachment



Design: Girders

- General Details
  - Intermediate Stiffeners
    - Weld to compression flange.
    - Tight fit (per AWS D1.5) to tension flange (not required, but may help fabricator to control flange tilt).
  - Compression Joints – Arch Members and Trusses
    - Fabricators prefer open joint w/ 100% bolts (vs. milled joint w/ 50% bolts).
    - Extra bolts less costly lessen field problems.
  - Connection Plates
    - Prefer bent connection plate vs. skewed connection plate for skewed cross frames.
    - Skew > 20 degrees may requires manual welding.

Design: Girders

- Skewed Cross Frame Connections

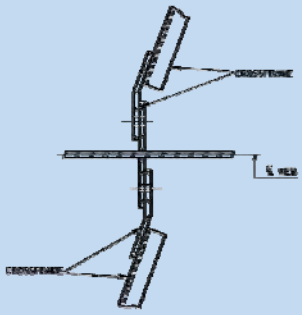


Figure 2.3.3A

Preferred (by fabricators)

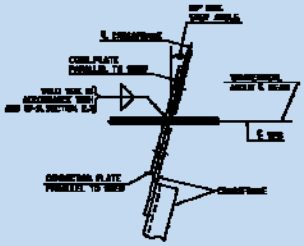


Figure 2.3.3B

20º maximum skew

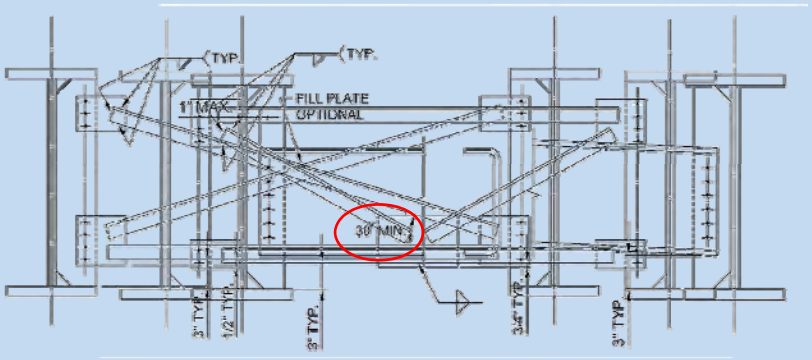
Design: Girders

Design: Girders

- General Details
  - Shop Assembly Requirements
    - Reconsider shop assembly for shallow curves.
    - Only require if truly concerned about fit in field.
  - Haunched Flange Transition
    - Allow bent or welded transition.
    - Straight haunch preferred over curved haunch.
  - Curved Girders
    - Allow for heat curve or cut curve.
  - Cross Frame design
    - Prefer X frame with use single angles.
    - K frame when angle of diagonals in X frame are too shallow.
    - Bent plate or channel for shallow girders (less than 48” deep) or for rolled beams.

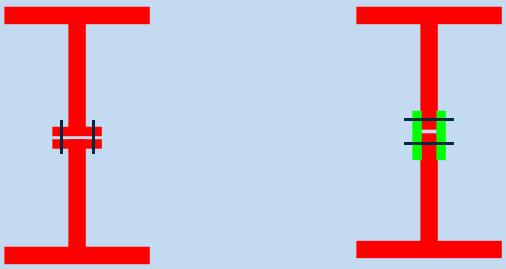
Design: Girders

- General Details
  - Cross Frame design



Design: Girders

- Longitudinal Web Field Splices (deep girders)



Preferred

Box Design

Design: Boxes

- Closed Box Configuration - Corner Welds
- Closed Box Diaphragm Attachment
- Closed Box Interior Diaphragm Minimum Access Hole Size
- Stiffener Detail at (near) Bottom Flange of Tub Girders
- Stiffening of Bottom Flange (Compression Zone)

Design: Boxes

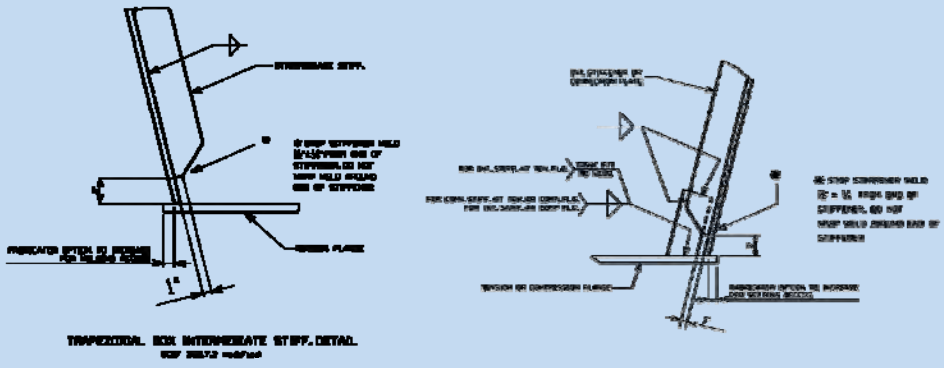
- Interior Coating
- Relative Costs of Closed Boxes and Tub Girders
- External Cross Frames

Design: Boxes

- Closed Box Configuration - Corner Welds
  - Try to arrange to use fillet welds
- Closed Box Diaphragm Attachment
  - Weld 3 sides, tight fit at tension flange
- Closed Box Interior Diaphragm Access Hole
  - 32 x 36 inches preferred (18 x 24 inches min)

Design: Boxes

Stiffener Detail at (near) Bottom Flange of Tub Girders



Design: Boxes

- Stiffening of Bottom Flange (Compression Zone)
  - Use WTs (versus bars)
  - Stop short of field splice (splice plates should adequately stiffen the flange)

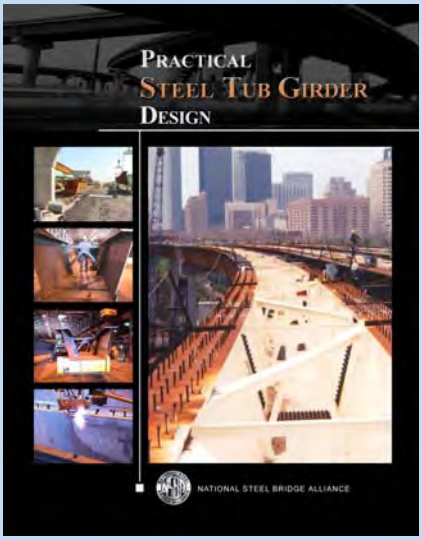
Design: Boxes

- Interior Coating
  - For inspection; single coat, light color
- Relative Costs of Closed Boxes and Tub Girders
  - No recommendation (box may be 20-30% more)
- External Cross Frames
  - At supports; for curved

Design: Boxes

NSBA website

- www.steelbridges.org



Bolts, Corrosion Protection and Shipping

Bolts

- Mechanically or Hot-Dip Galvanize
  - Mechanically galvanized preferred for painted structures.
  - Hot dip galvanized recommended for weathering steel applications; weathering steel bolts preferred.
- Shop Bolts – Black vs. Galvanized
  - Mechanically galvanized

Corrosion Protection

- Recommended Systems
  - Weathering Steel.
  - Three coat shop applied.
  - One shop primer with two additional field top coats.

Purchasing

- Bid Lump Sum
  - Except for emergency or repair
- Partial Payment for Materials and Fabrication
  - Pay for mill material received (per mill invoice)
  - Pay at completion of fabrication (70% of contract)
  - Pay at delivery to site or storage (90% of contract)
- Contract Direct w/ Fabricator
  - Can expedite delivery of fabricated steel

Shipping/Fabrication Piece Limits

- Most competitive sizing for shipping piece:
  - Length < 125 feet
  - Weight < 35 tons
  - Height < 9 feet tall
- Maximum fabricated segments for shipping (road):
  - Length < 175 feet (varies by state)
  - Weight < 80 tons (varies by state)
  - Height < 13.5 feet (on side) 9.5 feet (upright)

Conclusion

Collaboration Documents

NSBA website

- www.steelbridges.org

AASHTO bookstore

- www.transportation.org

Thank you…

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