Steel TIPS
STRUCTURAL STEEL EDUCATIONAL COUNCIL
TECHNICAL INFORMATION & PRODUCT SERVICE

August 2002

Cost Considerations for Steel Moment Frame Connections

by

Patrick M. Hassett
and
James J. Putkey

Acknowledgments

The Authors wish to thank the members of the Structural Steel Educational Council (SSEC) for their support in publishing this Steel *TIPS.* Special thanks are due to the following SSEC members and their firms for providing reviews and specific comments:

- Bill Honeck, Forell/Elsesser Engineers
- Brett Manning, The Herrick Corporation
- Rick Wilkinson, Gayle Manufacturing

COST CONSIDERATIONS FOR STEEL MOMENT FRAME CONNECTIONS

By Patrick M. Hassett and James J. Putkey

TABLE OF CONTENTS

1. INTRODUCTION

This section sets forth the purpose of the Steel *TIPS* and gives a history of why the authors selected the various connections and their cost considerations.

PURPOSE

This Steel *TIPS* informs engineers of the various cost considerations to construct ordinary and special moment frame connections.

Connections. The authors chose to gather information on 15 connections. These connections include:

- Nine prequalified connections addressed in FEMA-350.
- Three proprietary connections referenced in FEMA-350.
- Three connections included in previous Steel *TIPS.*

Limitations. This Steel *TIPS* does not comment on:

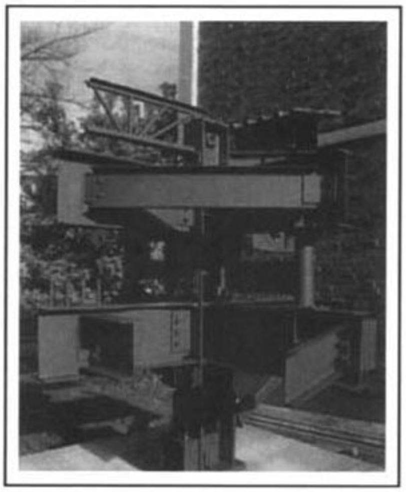
- Connection design, including performance during an earthquake.
- Relative Cost Factors of the different connections.
- Beam to column web connections.

HISTORY OF CONNECTIONS AND COST CONSIDERATIONS

1986 Steel *TIPS.* A 1986 Steel *TIPS,* "Steel Connections, Details and Relative Costs," gave relative costs of various types of connections—shear, non-moment, and moment. The *TIPS* authors used fabrication and erection costs to determine relative costs, but without showing cost items. Connection CF-1 in the *TIPS,* web bolted-flange butt welded, later known as the "pre-Northridge" connection, became the moment frame connection of choice with the lowest relative cost of 1.0.

Northridge Earthquake. During the Northridge Earthquake, the "pre-Northridge" connection experienced brittle fractures. See FEMA-350 for a background on the fractures. The brittle fractures showed a need for welding electrodes with higher notch toughness.

FEMA-350 Recommendations. FEMA-350 gives design recommendations on prequalified connections for ordinary and special moment frames. See AISC "Seismic Provisions for Structural Steel Buildings" for prequalification requirements. Rather than attempt to determine the lowest cost connection, the authors present cost considerations comparing connections shown in FEMA and other currently used connections to the "pre-Northridge" connection. This approach is intended to encourage the use of the variety of connections made available after the Northridge earthquake. This information also empowers the engineer to consider the preferences of local fabricators and erectors when selecting connection types.



2. CONNECTIONS

This Section presents the 15 selected connections.

ORGANIZATION

The following 30 pages show and discuss each of the 15 connections by showing the connection detail on one page and discussing the cost considerations on the opposite page.

The cost considerations include material, detailing, fabrication, shipping, erection, quality control, and quality assurance. Additionally, some connections include FEMA prequalification parameters for beam flange thickness. See FEMA-350 for complete prequalification data.

Each main cost consideration item includes sub-items appropriate to the main item. For example, fabrication includes sub-items for fit-up and welding.

DEVELOPMENT OF COST CONSIDERATIONS

The authors developed cost considerations based on their experience, and input from SSEC fabricators and erectors. Obviously, not all fabricators and erectors agreed with each other. Fabrication and erection methods vary according to the firm's size, equipment, personnel, and location. Engineers should consider those variations when designing a connection and reviewing shop drawings.

Cost consideration comments compare connections to the "pre-Northridge" connection shown in Appendix 1. The comment "standard[1] indicates the cost item considered has the same approximate cost as the "pre-Northridge" connection.

Chapter 3 gives a summary of the cost considerations in tabular format.

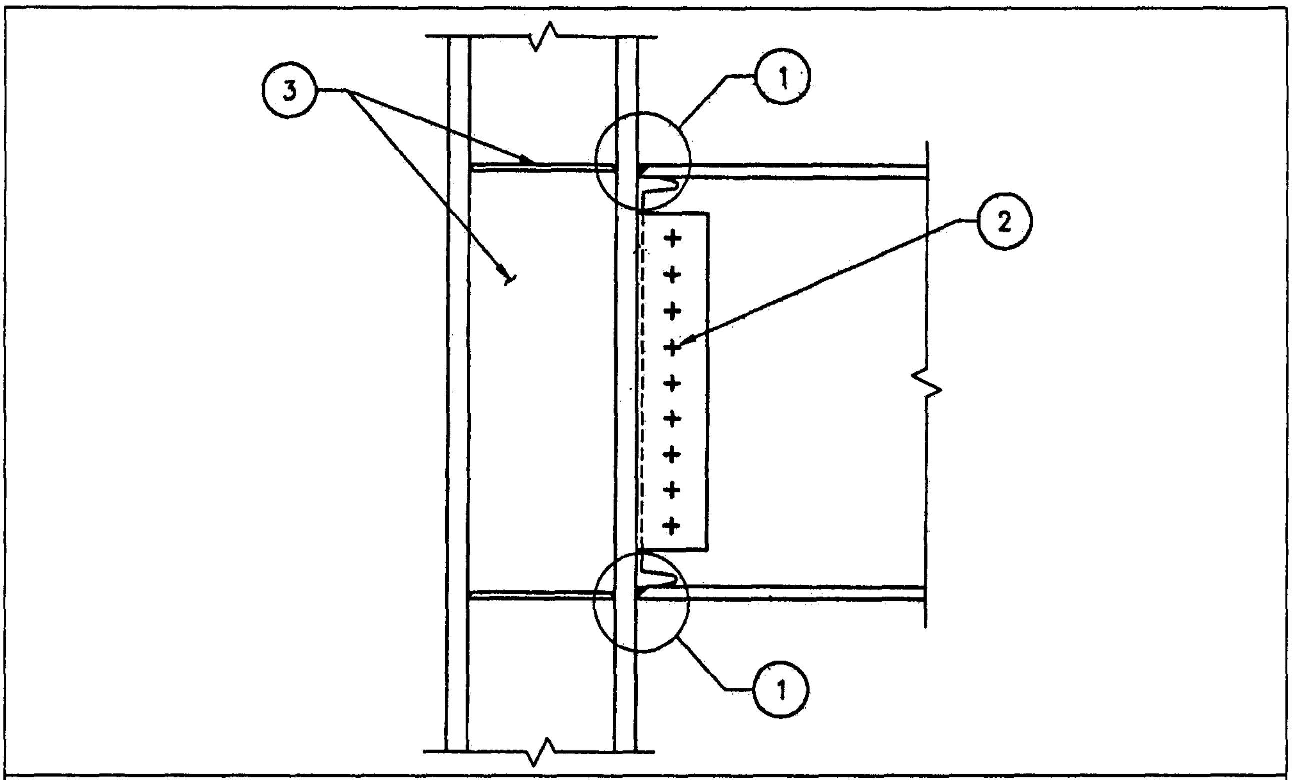
PROPRIETARY CONNECTIONS

Because of their nature, the authors needed permission from the patent holders to include proprietary connections in this *TIPS.* We included connections of patent holders who gave us the necessary permission.

EARTHQUAKE PERFORMANCE OF CONNECTIONS

Connections have different seismic performance characteristics. Please refer to FEMA reports for details regarding performance characteristics.

2.1 WELDED UNREINFORCED FLANGE - BOLTED WEB (WUF-B)



Notes

1. See Figure 3-8 and Note 1 of Figure 3-8 for top and bottom flange weld requirements. QC/QA category AH/T. Refer to Figure 3-5 for weld access hole detail.
2. Bolted shear tab. Use pretensioned A325 or A490 bolts. Weld to column flange with fillet weld both sides, or with CJP weld, to develop full shear strength of plate. Weld QC/QA Category BL/T.
3. See Figure 3-6 for continuity plate and web doubler plate requirements.

Figure 3-7 Welded Unreinforced Flange - Bolted Web (WUF-B) Connection

Reprinted from FEMA-350

Prequalification Data Considered.

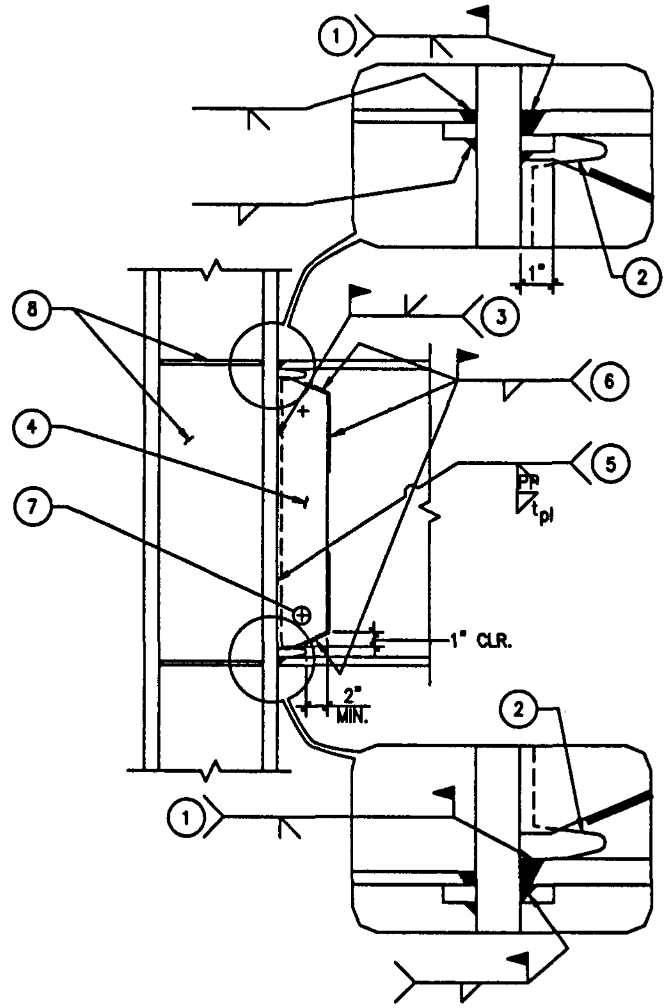
Type of frame: Ordinary Moment Frames (OMF) only
Maximum beam flange thickness: 1 inch

2.1 WELDED UNREINFORCED FLANGE - BOLTED WEB (WUF-B)

Cost Considerations

Material	Standard
Detailing	Weld access holes require special detailing.
Shop Fabrication	
Detail Parts	Standard
Main Parts	Weld access holes on beams require special work for cutting and grinding to roughness within 500 micro inches.
Fit-up	Standard
Welding	Weld for continuity plates and shear tabs on columns needs notch tough electrode with slower deposition rates.
Shipping	Standard
Erection	
Unloading	Standard
Shakeout	Standard
Erection	Standard
Plumb-up	Standard
Bolting	Standard
Welding	
Fit-up	Standard
Preheat	Standard
Welding	Notch tough electrode has slower deposition rates. Removal of back-up bar, back gouging, and fillet reinforcing is all overhead work and labor intensive.
Sequencing	Standard
Quality Control / Quality Assurance	See Appendix 2 for current QA recommended by FEMA-350 and 353.

2.2 WELDED UNREINFORCED FLANGE - WELDED WEB (WUF-W)



Notes

1. CJP groove weld at top and bottom flanges. At top flange, either (1) remove weld backing, backgouge, and add 5/16" minimum fillet weld, or (2) leave backing in place and add 5/16" fillet under backing. At bottom flange, remove weld backing, backgouge, and add 5/16" minimum fillet weld. Weld: QC/QA Category AH/T.
2. Weld access hole, see Figure 3-5.
3. CJP groove weld full length of web between weld access holes. Provide non-fusible weld tabs. Remove weld tabs after welding and grind end of weld smooth at weld access hole. Weld: QC/QA Category BH/T.
4. Shear tab of thickness equal to that of beam web. Shear tab length shall be so as to allow 1/8" overlap with the weld access hole at top and bottom, and the width shall extend 2" minimum back along the beam, beyond the end of the weld access hole.
5. Full-depth partial penetration from far side. Weld: QC/QA Category BM/T.
6. Fillet weld shear tab to beam web. Weld Size shall be equal to the thickness of the shear tab minus 1/16". Weld shall extend over the top and bottom one-third of the shear tab height and across the top and bottom. Weld: QC/QA Category BL/L.
7. Erection bolts: number, type, and size selected for erection loads.
8. For continuity plates and web doubler plates see Figure 3-6.

Figure 3-8 Welded Unreinforced Flange-Welded Web (WUF-W) Connection

Reprinted from FEMA-350

Prequalification Data Considered

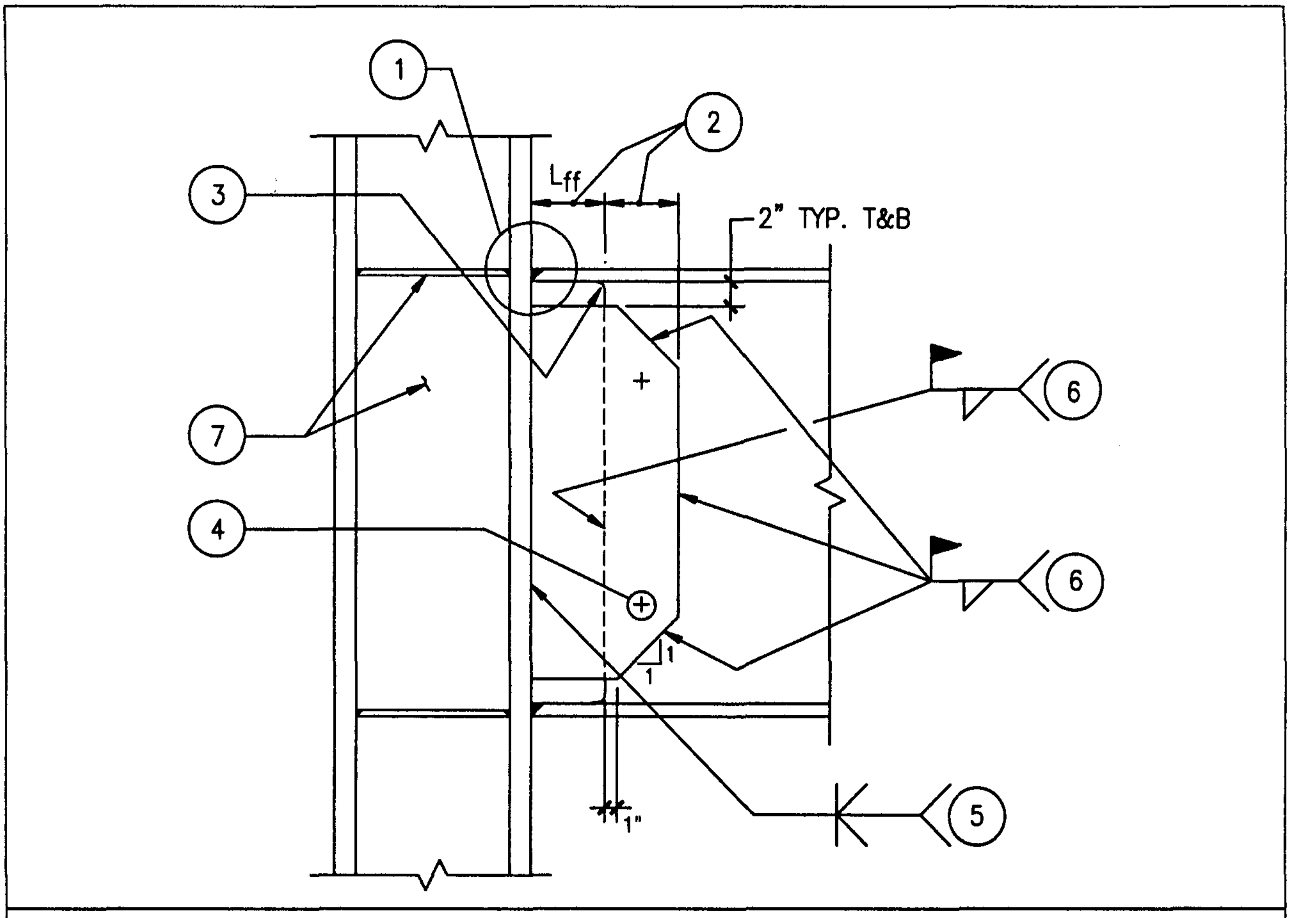
Type of frame: OMF, Special Moment Frame (SMF)
Maximum beam flange thickness: OMF - 1 ½ inch, SMF -1 inch

2.2 WELDED UNREINFORCED FLANGE - WELDED WEB (WUF-W)

Cost Considerations

Material	Standard
Detailing	Weld access holes require special detailing. Web welding requires special detailing to suit erector.
Shop Fabrication	
Detail Parts	Ends of column shear tabs require angled cuts adding labor to hand made plates. Column shear tabs require bevel preparation for weld to column.
Main Parts	Weld access holes on beams require special work. Fabricated roughness is required to 500 micro-inches.
Fit-up	Standard
Welding	Weld for continuity plates and shear tabs on columns needs notch tough electrode with slower deposition rates.
Shipping	Standard
Erection	
Unloading	Standard
Shakeout	Standard
Erection	Standard
Plumb-up	Standard
Bolting	Standard
Welding	
Fit-up	Tight fit-up of web to shear tab may require more bolts than determined for erection loads. Fit-up of web for CJP web weld can be difficult if fabrication is not done correctly.
Preheat	CJP and fillet welds for web require additional preheat.
Welding	Notch tough electrode has slower deposition rates. Removal of back-up bar, back gouging, and fillet reinforcing is all overhead work and labor intensive. Vertical CJP weld of beam web to column requires significant additional difficult welding. Skill level of welders and UT technicians are important factors to field production on these CJP welds. Non-fusible run-off tabs for web end weld require additional work in a cramped space. Fillet weld of beam web to shear tab requires significant additional welding.
Sequencing	Special sequencing is required when considering preheat, restraint, and cooling of welds.
Quality Control / Quality Assurance	See Appendix 2 for current QA recommended by FEMA-350 and 353.

2.3 WELDED FREE FLANGE (FF)



Notes

1. CJP groove weld. Note 1 of Figure 3-8 applies. Weld: QC/QA Category AH/T.
2. See design procedure in Section 3.5.3.1, Steps 5 through 8, for web plate size and thickness.
3. ½" minimum radius.
4. Erection bolts: number, type and size selected for erection loads.
5. CJP double-bevel groove weld. Weld: QC/QA Category BH/T.
6. Fillet welds size, length, calculated in Section 3.5.3.1, Step 8. Weld: QC/QA Category BH/L.
7. For continuity plates and web doubler plates see Figure 3-6.

Figure 3-9 Welded Free Flange (FF) Connection

Reprinted from FEMA-350

Prequalification Data Considered

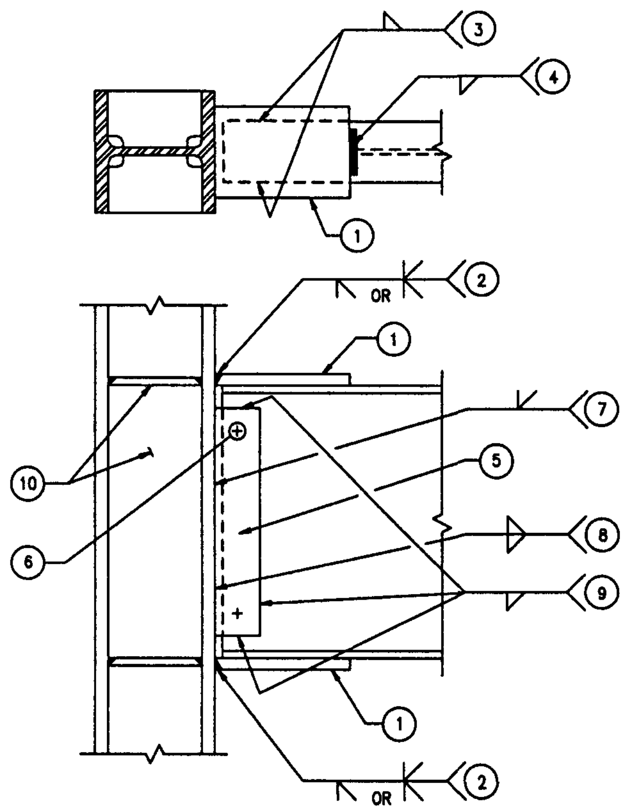
Type of frame: OMF, SMF
Maximum beam flange thickness: OMF - 1 1/4 inch, SMF - 3/4 inch

2.3 WELDED FREE FLANGE (FF)

Cost Considerations

Material	Larger shear tabs required.
Detailing	Special detailing required for girder web cut-out.
Shop Fabrication	
Detail Parts	Ends of column shear tabs require angled cuts; adding labor for hand made plates. Column shear tabs require double bevel preparation.
Main Parts	Beam web cut-out requires special work. Cutting in the fillet region of the web-flange intersection is difficult, especially when hand burned, with grinding required.
Fit-up	CJP weld for shear tab requires some additional fit-up work.
Welding	Weld for continuity plates and shear tabs on columns needs notch tough electrode with slower deposition rates. CJP weld for shear tab causes difficult welding distortion control.
Shipping	Standard, but wider shear tab on column must be watched. Care must be taken to avoid bending ends of beam flanges.
Erection	
Unloading	Standard
Shakeout	Standard
Erection	Standard
Plumb-up	The deep cut-out of the web may present plumb-up problems.
Bolting	Tight fit-up of web to shear tab may require more bolts than determined for erection loads.
Welding	
Fit-up	Standard
Preheat	Additional preheat required for shear tab fillet welding.
Welding	Notch tough electrode has slower deposition rates. Removal of back-up bar, back gouging, and fillet reinforcing is all overhead work and labor intensive. Additional shear tab fillet welding with multiple passes in vertical and overhead positions is likely.
Sequencing	Special sequencing required when considering preheat, restraint, and cooling of welds.
Quality Control / Quality Assurance	See Appendix 2 for current QA recommended by FEMA-350 and 353.

2.4 WELDED FLANGE PLATE (WFP)



Notes

1. Flange plate. See Section 3.5.4.1, Steps 1-4, for sizing requirements. Plates shall be fabricated with rolling direction parallel to the beam.
2. CJP groove weld: single or double bevel. Weld in shop or field. When using single-bevel groove weld, remove backing after welding, back-gouge, and reinforce with 5/16"-minimum fillet weld. When using double bevel weld, back-gouge first weld before welding other side. Weld QC/QA Category AH/T. If plates are shop welded to column, care must be exercised in locating and leveling plates, as shimming is not allowed between the plates and the beam flanges. If plates are field-welded to column after connecting to beam, weld access holes of sufficient size for weld backing and welding access shall be provided.
3. Fillet welds at edges of beam flanges to plate. Size welds according to the procedure in Section 3.5.4.1, Step 5. Welds may be shop or field. Provide weld tabs at end to provide full weld throat thickness to the end of the plate. Remove weld tabs and grind the end of the weld smooth. Use care to avoid grinding marks on the beam flange. Weld: QC/QA Category BH/L.
4. Fillet weld at end of flange plate to beam flange. Welds may be shop or field. Maintain full weld throat thickness to within 1" of the edge of the flange. Weld: QC/QA Category BH/T.
5. Shear tab of length equal to d_b-$2k$-2". Shear tab thickness should match that of beam web.
6. Erection bolts: number, type, and size selected for erection loads.
7. Full depth-partial penetration from far side. Weld: QC/QA Category BM/T.
8. Fillet weld both sides. Fillet on side away from beam web shall be same size as thickness of shear tab. Fillet on the side of the beam web shall be ½". Weld: QC/QA Category BH/T.
9. Fillet weld shear tab to beam web. Weld size shall be equal to the thickness of the shear tab minus 1/16". Weld: QC/QA Category BH/L.
10. For continuity plates and web doubler plates see Figure 3-6. For calculation of continuity plate requirements, use flange plate properties instead of beam flange properties.

Figure 3-11 Welded Flange Plate (WFP) Connection

Reprinted from FEMA-350

Prequalification Data Considered

Type of frame: OMF, SMF
Maximum beam flange thickness: OMF - 1 ½ inch, SMF - 1 inch

2.4 WELDED FLANGE PLATE (WFP)

Cost Considerations

Material

Extra material required for flange plates.
The authors consider the shop welding of both top and bottom flange plates impractical because of resulting erection tolerances. We consider a shop welded bottom plate and field welded top plate as the practical option.

Detailing

Special detailing is required for locating beam web to shear tab holes in relation to the bottom flange plate.

Shop Fabrication

Detail Parts — Flange plates require CJP bevel preparation, and shop must track rolling direction.

Main Parts — Beam does not require flange bevel preparation or access holes. Top flange needs a cope for back-up bar. Web requires bevel for PJP weld to shear tab.

Fit-up — Shear tab and bottom flange plate require additional fit-up. Bottom flange plate fit-up must be square and level.

Welding — Weld for continuity plates, shear tabs, and flange plates on columns needs notch tough electrode with slower deposition rates.
CJP welds on flange plates need distortion control.

Shipping

Column shipping takes more trailer space because of protruding flange plates.
Protruding flange plates require special care to avoid bending.

Erection

Unloading — Protruding flange plates require special care to avoid bending.

Shakeout — Column flange plates take some additional deck space.

Erection — Erection can be impaired if detailing and fabrication do not account for beam tolerances and if flange plates are not square to column.

Plumb-up — Proper sequencing of the top flange plate weld will eliminate problems of bay shrinkage with resulting benefits to plumb-up.

Bolting — Tight fit-up of web to shear tab may require more bolts than determined for erection loads.

Welding

Fit-up — The loose top flange plate allows field to set correct root openings.

Preheat — Less preheat required for fillet welds

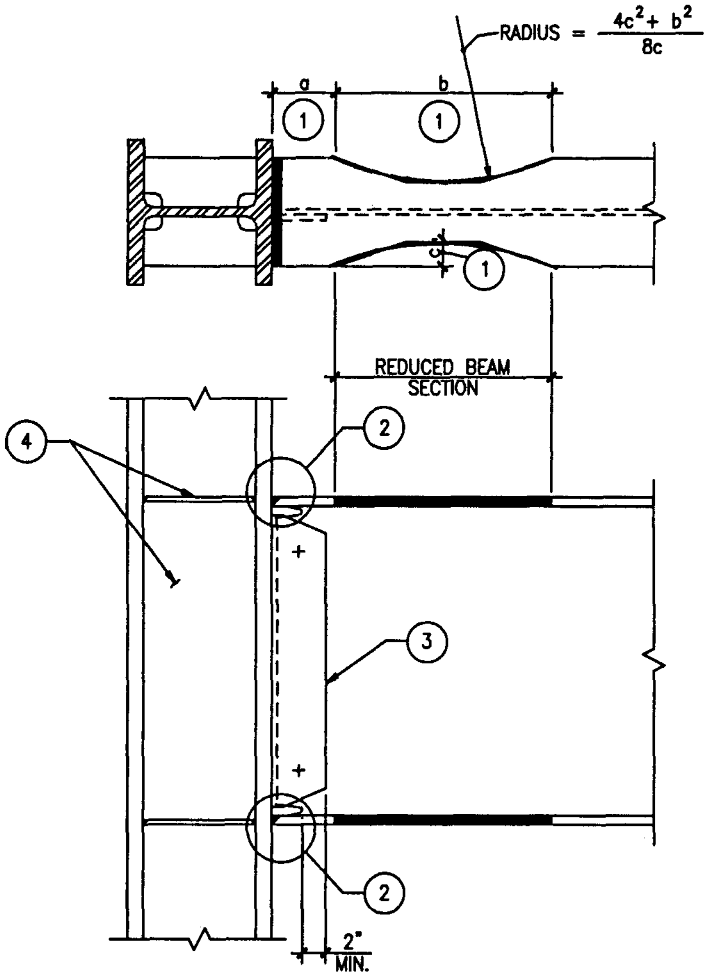
Welding — Notch tough electrode has slower deposition rates.
Removal required of back-up bars and run-off tabs on top flange plates.
Fillet welding in lieu of CJP welding is a benefit for the field.
Fillet weld of beam web to shear tab and vertical PJP weld of beam web to column require significant welding.
Possible gaps at bottom flange of beam to flange plate may require larger fillet welds.

Sequencing — Preheat, restraint, and cooling of web groove weld may require special sequencing.
Welders must follow a specified joint construction procedure.

Quality Control / Quality Assurance

See Appendix 2 for current QA recommended by FEMA-350 and 353.

2.5 REDUCED BEAM SECTION (RSB)



Notes

1. See Section 3.5.5.1 for calculation of RBS dimensions. See *FEMA-353, Recommended Specifications and Quality Assurance Guidelines for Steel Moment Frame Construction for Seismic Applications,* for fabrication details including cutting methods and smoothness requirements.
2. See Figure 3-8, and Note 1 to Figure 3-8, except that weld access hole may be as shown there, or as in AISC LRFD Vol. 1, Fig. C-J1.2, for rolled shapes or groove welded shapes.
3. Web Connection: Erection bolts: number, type, and size selected for erection loads.
   a. Alternative 1: CJP welded web. Weld QC/QA Category BM/L. Shear tab length is equal to the distance between the weld access holes plus ¼". Shear tab thickness is as required for erection and the tab serves as backing for CJP weld (3/8" min. thickness). Shear tab may be cut square, or tapered as shown. Weld of shear tab to column flange is minimum 3/16" fillet on the side of the beam web, and a fillet sized for erection loads (5/16" minimum) on the side away from the beam web. No weld tabs are required at the ends of the CJP weld and no welding of the shear tab to the beam web is required.Weld: QC/QA Category BM/L. Erection bolts are sized for erection loads.
   b. Alternative 2: Bolted shear tab. Shear tab and bolts are sized for shear, calculated as in Section 3.2 and using the methods of AISC. The shear tab should be welded to the column flange with a CJP groove weld or fillet of ¾ t_{pl} on both sides. Weld: QC/QA Category BL/T. Bolts shall be ASTM A325 or A490, and shall be fully-tightened.
4. For continuity plates and web doubler plates see Figure 3-6.

Figure 3-12 Reduced Beam Section (RBS) Connection

Reprinted from FEMA-350

Prequalification Data Considered

Type of frame: OMF, SMF
Maximum beam flange thickness: 1 3/4 inch

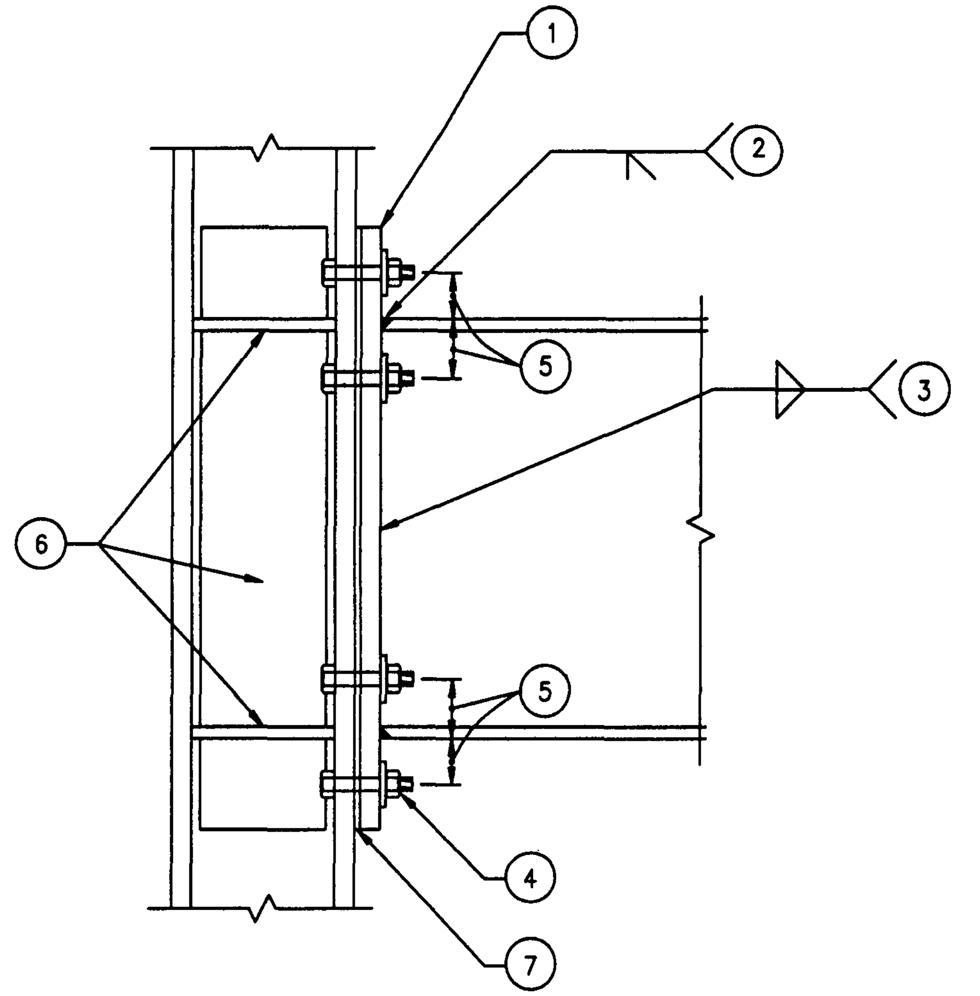
2.5 REDUCED BEAM SECTION (RBS)

Cost Considerations

(For welded web or bolted web options)

Material		Reduced section requires a slight increase in beam weight.
Detailing		Special detailing required for cut-out of flange reduced section and weld access holes.
Shop Fabrication		
	Detail Parts	End cuts on column shear tabs are not mandatory; increased cost if manually cut. Column shear tabs require large fillets, or bevel preparation and CJP if bolted option used.
	Main Parts	Weld access holes on beams require special work for cutting and grinding to roughness within 500 micro inches. Automated equipment provides more precise and efficient cutting of reduced beam sections. Reduced section cuts may require grinding. See FEMA-350 for repair recommendations. If welded web option used, then beam web requires beveled edge.
	Fit-up	More fit-up required for bolted web option because of CJP weld.
	Welding	Weld for continuity plates and shear tabs on columns needs notch tough electrode with slower deposition rates. Bolted web option requires CJP or heavy fillet weld on shear tab.
Shipping		Standard
Erection		
	Unloading	Standard
	Shakeout	Standard
	Erection	Standard
	Plumb-up	Standard
	Bolting	Standard, but tight fit-up of web to shear tab may require more bolts than determined for erection loads.
	Welding	
	Fit-up	Standard for bolted option. Welded web option may be more difficult if fabrication tolerances are not controlled.
	Preheat	Standard for bolted option; welded web requires additional preheat.
	Welding	Notch tough electrode has slower deposition rates. Removal of back-up bar, back gouging, and fillet reinforcing is all overhead work and labor intensive. CJP weld of beam web to column requires significant additional welding.
	Sequencing	Special sequencing is required for welded web option when considering preheat, restraint, and cooling of welds.
Quality Control / Quality Assurance		See Appendix 2 for current QA recommended by FEMA-350 and 353.

2.6 BOLTED UNSTIFFENED END PLATE (BUEP)



Notes

1. ASTM A36 end plate. For sizing see Section 3.6.1.1.
2. CJP groove weld. This weld has special requirements. See *FEMA-353, Recommended Specifications and Quality Assurance Guidelines for Steel Moment Frame Construction for Seismic Applications,* for fabrication details. Weld: QC/QA Category AH/T.
3. Fillet weld both sides, or CJP weld; see Section 3.6.1.3 for sizing requirements. See *FEMA-353, Recommended Specifications and Quality Assurance Guidelines for Steel Moment Frame Construction for Seismic Applications,* for fabrication details. Weld: QC/QA Category BM/L.
4. Pretensioned ASTM A325 or A490 bolts. Diameter not to exceed 1-1/2 inch. See Section 3.6.1.1 for sizing requirements.
5. Bolt location is part of the end plate design. See Section 3.6.1.1.
6. For continuity plates and web doubler plates, see Figure 3-6. For calculation of panel zone strength, see Section 3.6.1.1.
7. Shim as required. Finger shims shall not be placed with fingers pointing up.

Figure 3-13 Bolted Unstiffened End Plate (BUEP) Connection

Reprinted from FEMA-350

Prequalification Data Considered

Type of frame: OMF, SMF
Maximum beam flange thickness: 3/4 inch

2.6 BOLTED UNSTIFFENED END PLATE (BUEP)

Cost Considerations

Material — Heavy end plate, shims, and longer doubler plates add significant material cost.

Detailing — Special detailing is required for end plates and to allow for erection clearances, column depth over-run tolerances, column flange twist tolerance, and shimming.

Shop Fabrication

Detail Parts — End plate holes must be precisely located to match column holes. Automated equipment provides more precise and efficient plate cutting and hole drilling.

Main Parts — Hole drilling on column flange must be precise to match end plate holes; best made with automated fabrication equipment.
No weld access holes are required.

Fit-up — Positioning of end plate requires careful fit-up on beam.

Welding — CJP of beam flanges to end plate requires additional shop welding.
Notch tough electrode has slower deposition rates.
No web bolt holes or weld access holes required. Note: The CJP flange weld is made without a weld access hole; testing has shown this procedure acceptable.

Shipping — End plates may require additional cribbing.

Erection

Unloading — Extended end plate causes handling problems.

Shakeout — End plates require additional blocking on deck.

Erection — End plates present the problem of fitting the beam between the column flanges resulting in extra erection time including expensive crane time.

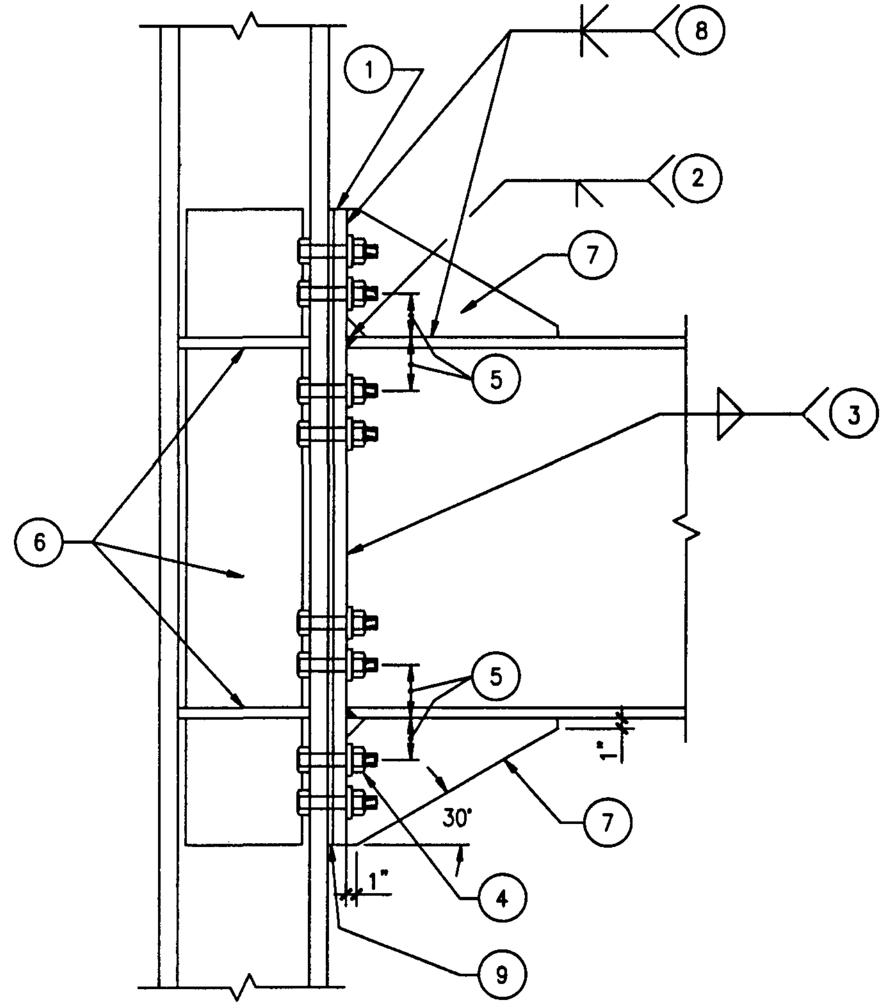
Plumb-up — Plumb-up is difficult due to fixity of connection and shimming.
Column depth tolerance can throw off bay widths.
Shimming is required to obtain correct bay width.

Bolting — The shimming required is time consuming.
Bolt fit-up and installation may be a problem if fabrication is imperfect.
Misaligned holes may require reaming.
Bolt sizes greater than 1 1/8 inch diameter require heavier equipment to fully tension.

Welding — No field welding is required.

Quality Control / Quality Assurance — Welding quality control and quality assurance are shifted from the field to the shop.
Shop must perform more careful fabrication with resulting quality control increase.
Absence of weld access hole simplifies UT at web intersection.
See Appendix 2 for current QA recommended by FEMA-350 and 353.

2.7 BOLTED STIFFENED END PLATE (BSEP)



Notes

1. ASTM A36 end plate. For sizing, see Section 3.6.2.1.
2. CJP groove weld. This weld has special requirements. See *FEMA-353, Recommended Specifications and Quality Assurance Guidelines for Steel Moment Frame Construction for Seismic Applications,* for fabrication details. Weld: QC/QA Category AH/T.
3. Fillet weld both sides, or CJP weld; see Section 3.6.2.4 for sizing requirements. See *FEMA-353, Recommended Specifications and Quality Assurance Guidelines for Steel Moment Frame Construction for Seismic Applications,* for fabrication details. Weld: QC/QA Category BM/L.
4. Pretensioned ASTM A325 or A490 bolts. See Section 3.6.2.1 for sizing requirements.
5. Bolt location is part of the end plate design. See Section 3.6.2.1.
6. For continuity plates and web doubler plates, see Figure 3-6. For calculation of panel zone strength, see Section 3.6.2.1.
7. Stiffener is shaped as shown. Stiffener thickness shall be the same as that of the beam web.
8. Stiffener welds are CJP double-bevel groove welds to both beam flange and end plate. Weld: QC/QA Category AH/T for weld to endplate. BM/L for weld to beam..
9. Shim as required. Finger shims shall not be placed with fingers pointing up.

Figure 3-15 Stiffened End Plate Connection

Reprinted from FEMA-350

Prequalification Data Considered

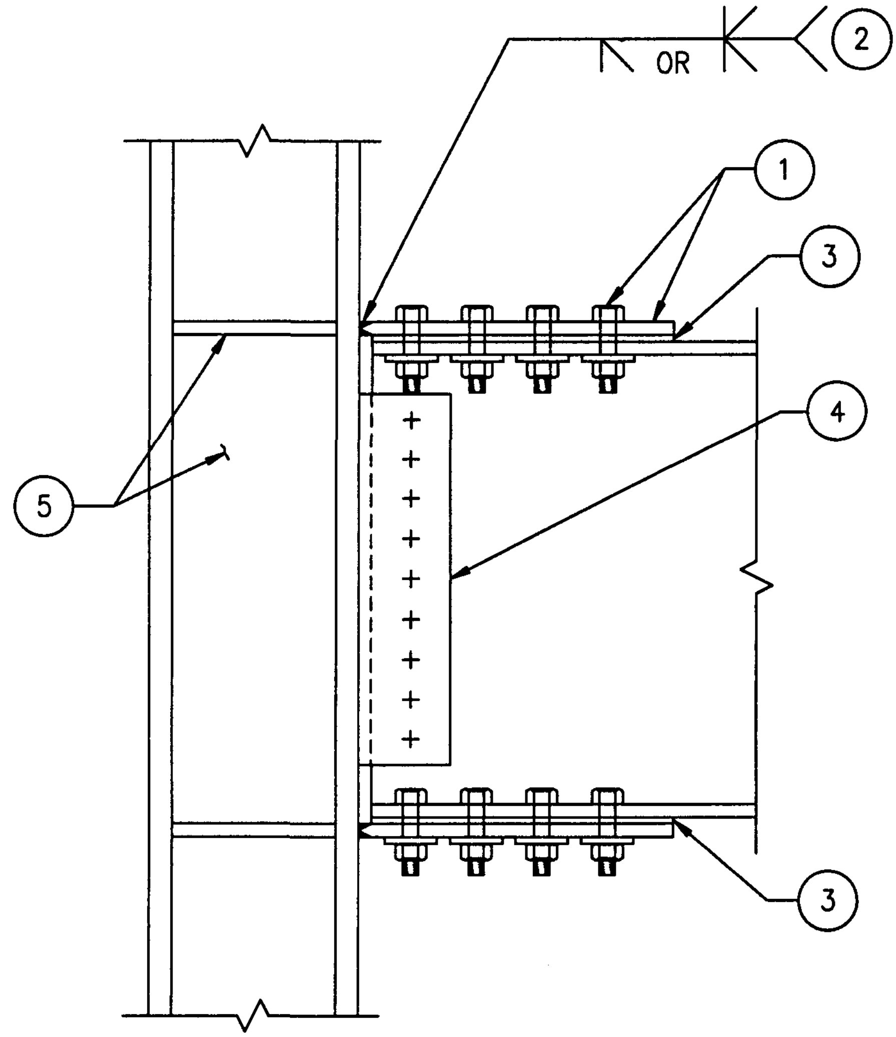
Type of frame: OMF, SMF
Maximum beam flange thickness: 1 inch

2.7 BOLTED STIFFENED END PLATE (BSEP)

Cost Considerations

Material	Heavy end plates, stiffeners, shims, and longer doubler plates add significant material cost.
Detailing	Special detailing is required to allow for erection clearances, column depth over-run tolerances, column flange twist tolerance, and shimming. End plates and stiffeners require additional detailing.
Shop Fabrication	
Detail Parts	End plate holes must be precisely located to match column holes. Automated equipment provides more precise and efficient fabrication.
Main Parts	Hole drilling on column flange must be precise to match end plate holes; best made with automated fabrication equipment. No weld access holes are required.
Fit-up	Positioning of end plate requires careful fit-up. Stiffener plates require additional fit-up work.
Welding	CJP of beam flanges to end plate requires additional shop welding. Notch tough electrode has slower deposition rates. No web bolt holes or weld access holes required. Note: The CJP flange weld is made without a weld access hole; testing has shown this procedure acceptable. Stiffener plate CJP weld to end plate may cause end plate distortion. Multiple positioning of beam requires more rolling of beam due to CJP at top flange, bottom flange, and stiffener plates.
Shipping	Beams take more trailer space and require more cribbing because of end plates.
Erection	
Unloading	Stiffened end plate causes handling problems.
Shakeout	End plates require additional blocking on deck.
Erection	End plates present the problem of fitting the beam between the column flanges resulting in extra erection time including expensive crane time. Stiffener plates may distort the end plate, causing additional erection problems.
Plumb-up	Plumb-up is difficult due to fixity of connection and shimming. Column depth tolerance can throw off bay widths. Shimming is required to obtain correct bay width.
Bolting	The shimming required is time consuming. Bolt fit-up and installation may be a problem if fabrication is not nearly perfect. Misaligned holes may require reaming. Bolt sizes greater than 1 1/8 inch diameter require heavier equipment to fully tension. Increased number of holes increases probability of misalignment.
Welding	No field welding is required.
Quality Control / Quality Assurance	Welding quality control and quality assurance are shifted from the field to the shop. Shop must perform more careful fabrication with resulting quality control increase. Absence of Weld access holes simplifies UT at web intersection. See Appendix 2 for current QA recommended by FEMA-350 and 353.

2.8 BOLTED FLANGE PLATE (BFP)



Notes

1. Size the flange plate and bolts in accordance with Section 3.6.3.1. Bolts are fully pretensioned ASTM A325 or A490, designed for bearing. Bolt holes in flange plate are oversize holes. Use standard holes in beam flange. Washers as required by RCSC, Section 7.
2. CJP groove weld, single or double bevel. Weld in shop or field. When using single-bevel groove weld, remove backing after welding, backgouge, and reinforce with 5/16" minimum fillet weld. When using double bevel weld, backgouge first weld before welding other side. Weld: QC/QA Category AH/T.
3. Shims are permitted between flange plates and flanges.
4. Size shear tab and bolts by design procedure in Section 3.6.3.2. Bolt holes in shear tab are short-slotted-horizontal; holes in web are standard. Weld QC/QA Category BM/L.
5. For continuity plates and web doubler plates see Figure 3-6. For calculation of continuity plate requirements, use flange plate properties as flange properties.

Figure 3-17 Bolted Flange Plate (BFP) Connection

Reprinted from FEMA-350

Prequalification Data Considered

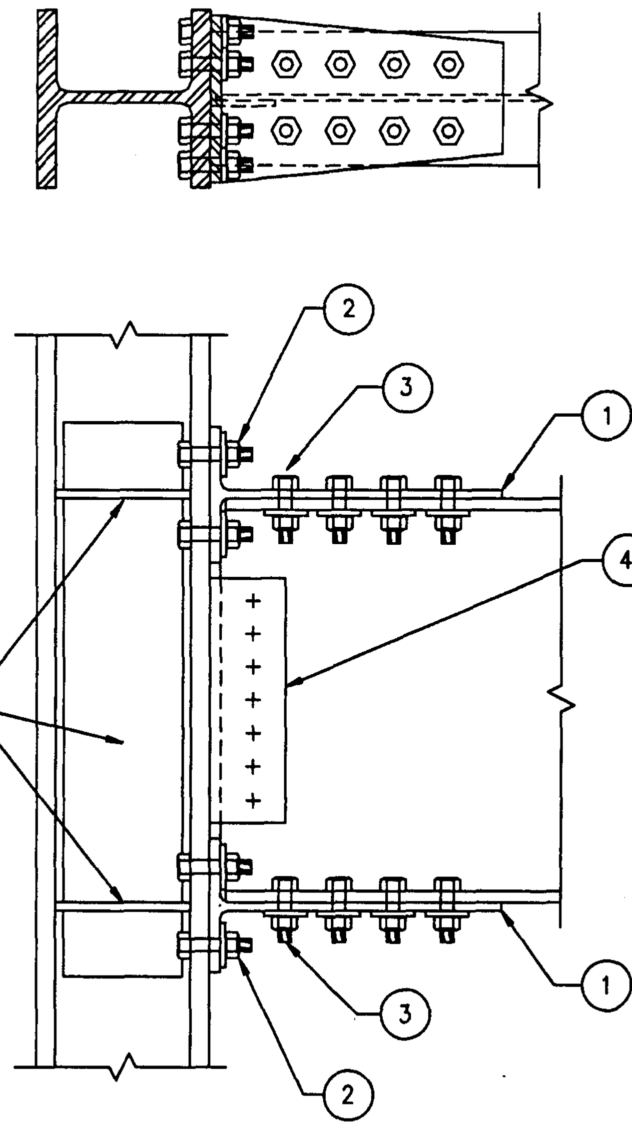
Type of frame: OMF, SMF
Maximum beam flange thickness: OMF - 1 1/4 inch, SMF - 3/4 inch

2.8 BOLTED FLANGE PLATE (BFP)

Cost Considerations

Material	Flange plates and shims add additional material. The authors consider shop welded, field bolted flange plates as the practical option since shimming facilitates the necessary erection tolerances.
Detailing	Special detailing required to allow for beam depth over-run tolerance, beam flange twist tolerance, and shimming for shop attached flange plates.
Shop Fabrication	
Detail Parts	Flange plate holes must be precisely located to match beam flange holes. Flange plates require bevel preparation. Shop must track rolling direction.
Main Parts	Hole drilling on beam flanges must be precise. Automated equipment provides more precise and efficient fabrication. No weld access holes required on beams.
Fit-up	Flange plate fit-up must be carefully braced square and level and allowance made for weld shrinkage.
Welding	Weld for continuity plates, shear tabs, and flange plates on columns needs notch tough electrode with slower deposition rates. CJP beam flange plate weld to column adds shop welding, but weld is better positioned in shop and protected from weather. Flange plate angular distortion must be controlled during welding.
Shipping	Column shipping takes more trailer space because of protruding flange plates. Protruding flange plates require special care to avoid bending.
Erection	
Unloading	Protruding flange plates require special care to avoid bending.
Shakeout	Column flange plates take some additional deck space.
Erection	Can go smoothly if flange plates are straight. Sufficient gap must be made between flange plates to allow quick erection between columns.
Plumb-up	Bolts in flange plates may help plumb-up process by keeping bays from racking.
Bolting	Required shimming is time consuming. Oversized holes in flange plates and slotted holes in shear tabs will help hole alignment. Bolt sizes greater than 1 1/8 inch diameter require heavier equipment to fully tension.
Welding	No field welding.
Quality Control / Quality Assurance	Weld quality control and quality assurance are shifted from the field to the shop. See Appendix 2 for current QA recommended by FEMA-350 and 353.

2.9 DOUBLE SPLIT TEE (DST)



Notes

1. Split Tee: length, width, and thickness determined by design according to Section 3.7.1.2.
2. Fully pretensioned ASTM A325 or A490 bolts in standard holes sized for bearing. For sizing, see Section 3.7.1.2, Step 7.
3. Fully pretensioned ASTM A325 or A490 bolts in standard holes sized for bearing. For sizing, see Section 3.7.1.2, Step 4.
4. Shear tab welded to column flange with either CJP weld or two-sided fillet weld. For calculation of design strength of shear tab, welds, and bolts, see Section 3.7.1.2, Step 14. Weld: QC/QA Category BM/L.
5. For continuity plates and web doubler plates see Figure 3-6.

Figure 3-20 Double Split Tee (DST) Connection

Reprinted from FEMA-350

Prequalification Data Considered

Type of frame: OMF, SMF

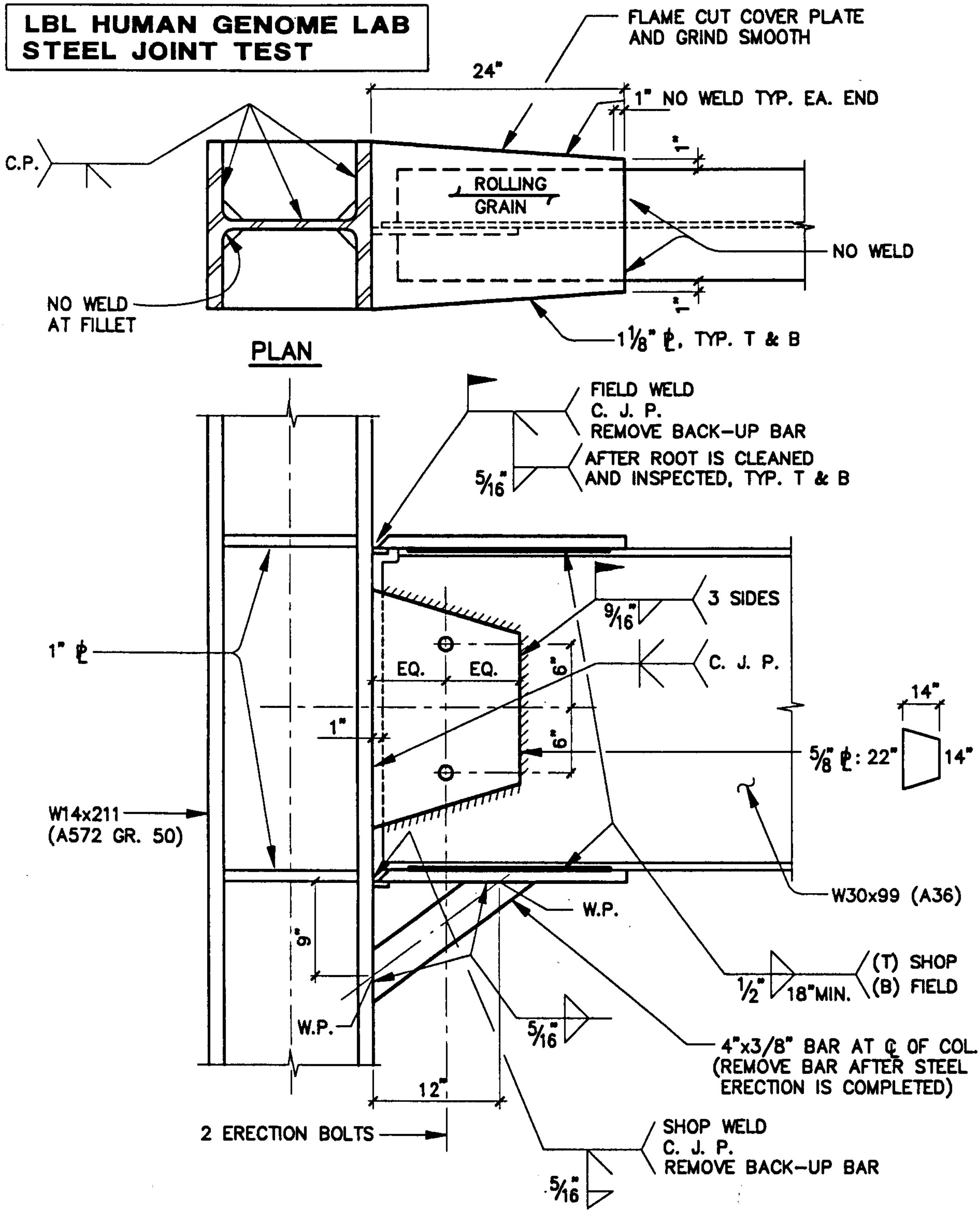
2.9 DOUBLE SPLIT TEE (DST)

Cost Considerations

Material	Split tees and shims add additional material.
Detailing	Special detailing required to allow for beam and column depth over-run tolerance, beam flange twist tolerance, and shimming.
Shop Fabrication	
Detail Parts	Split tee holes must be precisely located to match beam flange holes and column flange holes. Automated equipment provides more precise and efficient fabrication. Commonly, tees are cut from W shapes to make WT shapes.
Main Parts	Hole drilling on beam flanges and column flanges must be precise, best made with automated fabrication equipment. No weld access holes required on beams.
Fit-up	Shear tab is more easily fit-up when fillet welded.
Welding	Weld for continuity plates, shear tabs, and doubler plates on columns needs notch tough electrode with slower deposition rates.
Bolting	Split tee positioning must be carefully made square and level and allowance made for shim compression.
Shipping	Beam or column shipping takes more trailer space because of protruding split tees. Protruding split tees require special care to avoid bending.
Erection	
Unloading	Protruding split tees require special care to avoid bending.
Shakeout	Split tees on columns or beams need special cribbing.
Erection	Can go smoothly if split tees are straight. A bend in WT web will hold up erection due to beam getting jammed between columns.
Plumb-up	Standard.
Bolting	Required shimming is time consuming. Standard holes specified may require reaming. Bolt sizes greater than 1 1/8 inch diameter require heavier equipment to fully tension.
Welding	No field welding.
Quality Control / Quality Assurance	Weld quality control is shifted from the field to the shop. See Appendix 2 for current QA recommended by FEMA-350 and 353.

2.10 WELDED FLANGE PLATE - TOP PLATE ON BEAM (WFP-ALT.1)

This connection is a version of the Welded Flange Plate (WFP) Connection. The top flange plate is shop fillet welded to the beam.



Prequalification Data Considered

Forell/Elsesser Engineers qualified this connection by test for a specific column and beam combination on a specific project.

2.10 WELDED FLANGE PLATE - TOP PLATE ON BEAM (WFP-ALT.1)

Cost Considerations

Material — Flange plates require extra material.

Detailing — Locating beam web holes and shear plate holes with bottom flange plate requires special detailing.

Shop Fabrication

- **Detail Parts** — Column shear tabs require CJP bevel preparation.
  Flange plates require CJP bevel preparation.
  Flange plates require cutting to fit flange width. Automated equipment provides more precise and efficient fabrication. Shop must track rolling direction.
- **Main Parts** — Beam does not require bevel preparation or access holes.
  Cope required at top flange.
- **Fit-up** — Bottom flange plate and shear plate require careful fit-up to ensure tolerances are kept.
- **Welding** — Weld for continuity plates, shear plate, and bottom flange plate on column needs notch tough electrode with slower deposition rates.
  CJP weld on shear plate and bottom flange plate need distortion control.

Shipping — Column shipping takes more trailer space because of protruding flange plates.

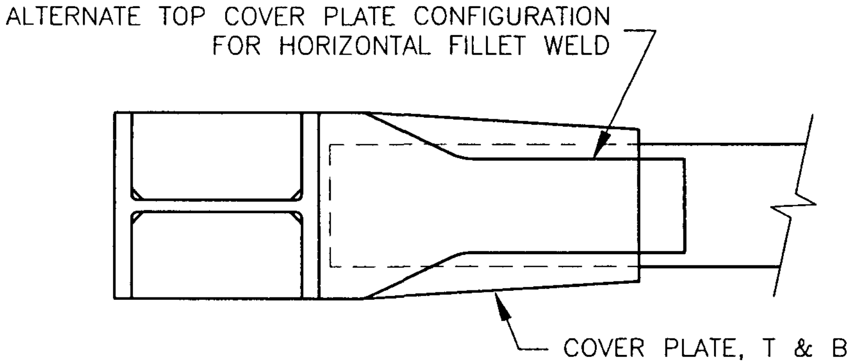
Erection

- **Unloading** — Protruding flange plates require special care to avoid bending.
- **Shakeout** — Column flange plates take some additional deck space.
- **Erection** — Bottom plate could cause problems for connecting if not fabricated with care.
- **Plumb-up** — Standard
- **Bolting** — Web connection requires only two erection bolts.
- **Welding**
  - **Fit-up** — May need to clamp bottom flange plate to bottom flange of beam.
    Field must remove shop fit-up bar on bottom flange plate.
  - **Preheat** — Fillet welds require less preheat.
  - **Welding** — Notch tough electrode has slower deposition rates.
    Back-up bar removal and fillet weld reinforcement requires work in overhead position.
    Fillet welding of bottom flange plate to beam flange requires significant welding, but in horizontal position.
    Fillet weld of beam web to shear tab requires significant welding, some in overhead and vertical positions.
  - **Sequencing** — Special sequence is required when considering preheat, restraint, and cooling of welds.

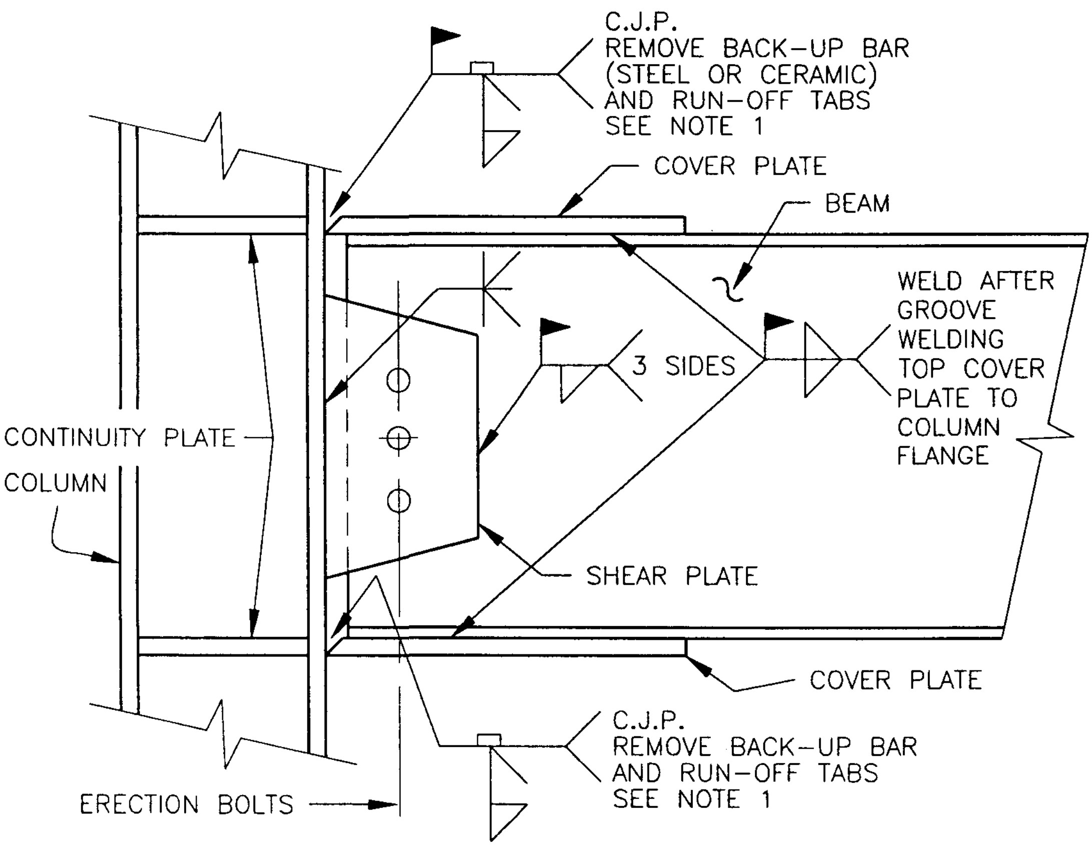
Quality Control / Quality Assurance — Since top flange plate CJP weld is not impaired by beam web, it is inherently a weld that has less problems with quality and UT.
See Appendix 2 for current QA recommended by FEMA-350 and 353.

2.11 WELDED FLANGE PLATE - LOOSE TOP PLATE (WFP-ALT. 2)

This connection is a version of the Welded Flange Plate (WFP) connection. The top flange plate is shipped loose. See Reference 5 for connection origin.



PLAN



NOTE 1. GRIND SMOOTH TO REMOVE STRESS RISERS AND LAYER OF MARTENSITE FROM BURNING OPERATION

ELEVATION

Reprinted from Steel TIPS, see Reference 5

Prequalification Data Considered

This connection lacks prequalification.

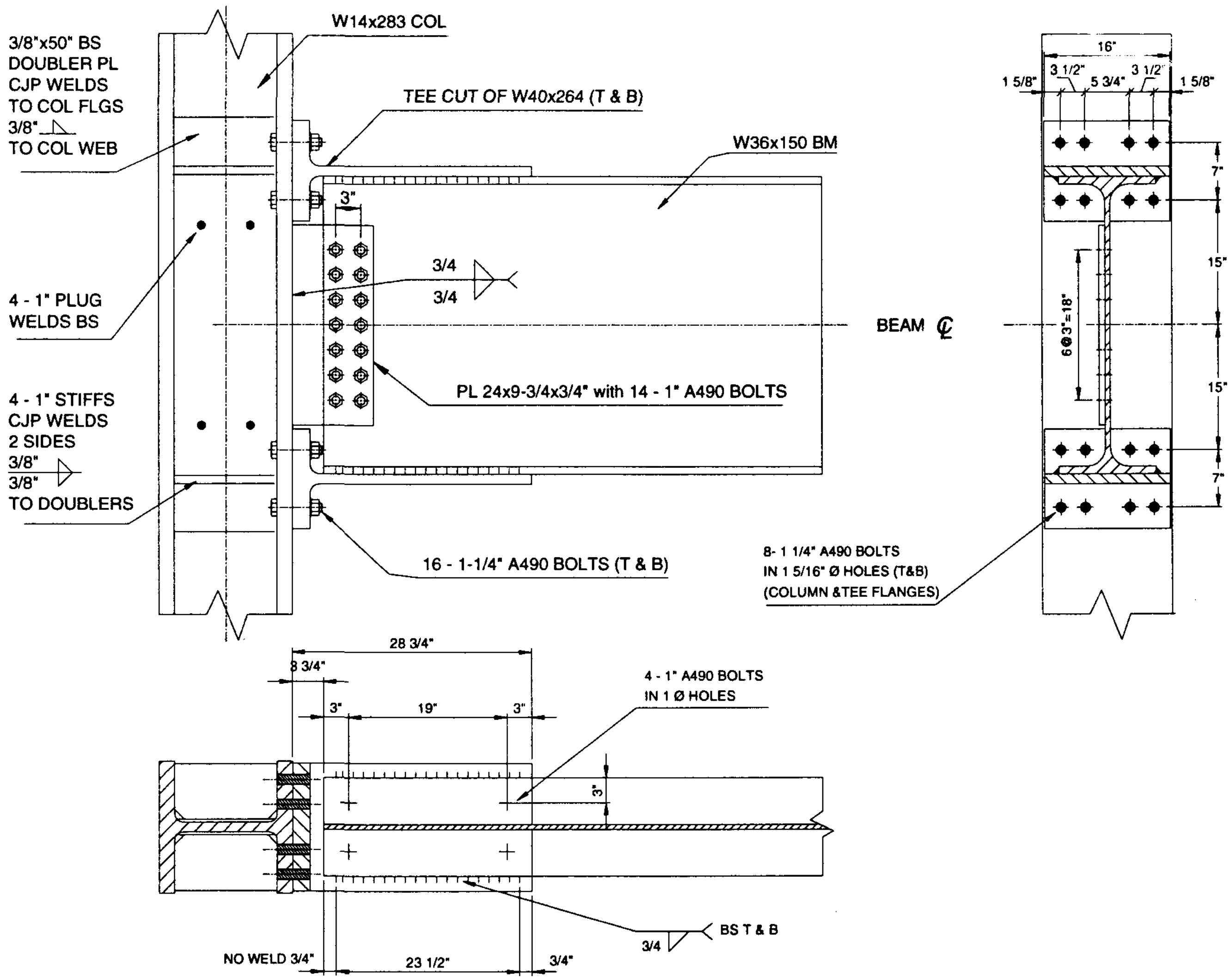
2.11 WELDED FLANGE PLATE - LOOSE TOP PLATE (WFP-ALT.2)

Cost Considerations

Material	Flange plates require extra material.
Detailing	Locating beam web holes and shear plate holes with bottom flange plate requires special detailing. The absence of restrained field welds eliminates the need to provide for weld shrinkage.
Shop Fabrication	
Detail Parts	Column shear tabs require CJP bevel preparation. Flange plates require CJP bevel preparation. Flange plates require cutting to fit flange width, an operation best suited for automated fabrication equipment.
Main Parts	Beam does not require bevel preparation or access holes.
Fit-up	Bottom flange plate and shear plate require careful fit-up to ensure tolerances are kept.
Welding	Weld for continuity plates, shear plate, and bottom flange plate on column needs notch tough electrode with slower deposition rates. CJP weld on shear plate and bottom flange plate need distortion control.
Shipping	Column shipping takes more trailer space because of protruding flange plates.
Erection	
Unloading	Protruding flange plates require special care to avoid bending.
Shakeout	Column flange plates take some additional deck space.
Erection	If not properly fabricated, bottom plate could cause problems aligning beam web holes with column shear tab holes.
Plumb-up	Tightening of web bolts before welding sets column bay spacing. Welding will not effect column spacings with resulting benefits to plumb-up.
Bolting	Web connection requires only three erection bolts.
Welding	
Fit-up	Top and bottom flange plates may require clamping to beam flanges.
Preheat	Fillet welds require less preheat.
Welding	Notch tough electrode has slower deposition rates. Back-up bar removal and fillet weld reinforcement requires work in overhead position. Fillet welding of top and bottom flange plates to beam flanges requires significant welding, half in overhead position. Fillet weld of beam web to shear tab requires significant welding, some in overhead and vertical positions. Possible gaps at bottom flange of beam to flange plate may require larger fillet welds.
Sequencing	Welders must make CJP weld on top flange plate before fillet welding plate to beam. No other joint, connection, or bay sequencing is required.
Quality Control / Quality Assurance	See Appendix 2 for current QA recommended by FEMA-350 and 353.

2.12 DOUBLE SPLIT TEE - TEES ON BEAM (DST-ALT.1)

This connection is a variation of the Double Split Tee (DST) connection. The split tees are shop fillet welded to the beam flange.



Reprinted from Steel TIPS, see Reference 9

Prequalification Data Considered

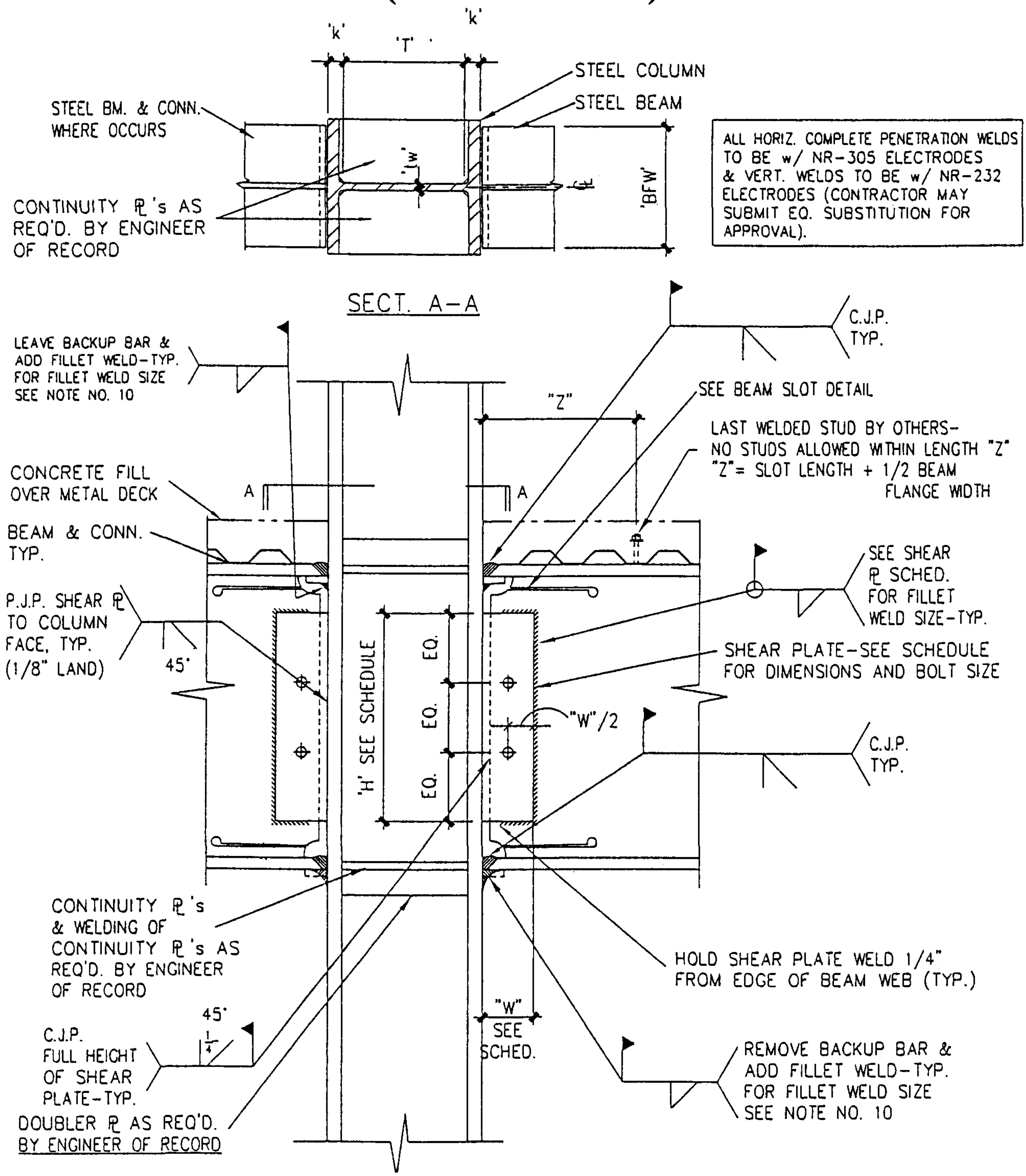
Professor Popov tested this connection for a specific column and beam size. See Reference 9.

2.12 DOUBLE SPLIT TEE - TEES ON BEAM (DST-ALT.1)

Cost Considerations

Material	Split tees, longer doubler plates, larger shear tabs, and shims add additional material. Shims are required between WT flanges and column flange.
Detailing	Special detailing required to allow for beam and column depth over-run tolerance and shimming.
Shop Fabrication	
Detail Parts	Split tee holes must be precisely located to match column flange holes. Commonly, tees are cut from W shapes to make WT shapes.
Main Parts	Hole drilling on column flanges must be precise, an operation best suited for automated fabrication equipment. No weld access holes required on beams. Beams require no flange bevel preparation.
Fit-up	Split tee fit-up must be carefully made square and level and allowance made for shim compression. Fillet welded shear tab requires careful fit-up to match beam web holes.
Welding	Weld for continuity plates, shear tabs, and doubler plates on columns and tees to beam flanges needs notch tough electrode with slower deposition rates.
Bolting	The only shop bolting is the four bolts for each tee.
Shipping	Beam shipping takes more trailer space because of protruding split tees. Protruding split tees require special care to avoid bending.
Erection	
Unloading	Protruding split tees require special care to avoid bending.
Shakeout	Beam split tees take some additional cribbing to properly stack on deck prior to erecting.
Erection	Shop welded split tees may cause erection problems because beams need to be entered sideways.
Plumb-up	Standard
Bolting	Required shimming between split tee flanges and column flanges is time consuming. 1 1/4 inch diameter bolts require heavier equipment to fully tension.
Welding	No field welding.
Quality Control / Quality Assurance	Weld quality control is shifted from the field to the shop, and CJP welds are replaced with fillet welds. See Appendix 2 for current QA recommended by FEMA-350 and 353.

2.13 SLOTTED BEAM (PROPRIETARY)



SSDA BEAM SLOT CONNECTION- Prequalified by ICBO (ER -5861) 1

U.S. Patent Nos. 5,680,738 & 6,237,303

Reprinted from "Slotted Web connection Manual." See Reference 10.

Prequalification Data Considered.

Type of frame: OMF and SMF

The patent holder, SSDA, has qualified this connection for various beam/column combinations, including columns greater than W14.

2.13 SLOTTED BEAM (PROPRIETARY)

Cost Considerations

Material Standard, but there is an added cost for using the proprietary system.

Detailing Weld access holes and beam web slots require special detailing.
Web welding requires special detailing depending on beam sizes.

Shop Fabrication

Detail Parts Standard

Main Parts Weld access holes and beam slots require special work. Automated equipment provides more precise and efficient fabrication.

Fit-up Standard

Welding Welds for continuity plates, if those plates are required by the engineer, and shear tabs on columns need notch tough electrode with slower deposition rates.

Shipping Standard

Erection

Unloading Standard

Shakeout Standard

Erection Standard

Plumb-up Due to web flexibility, some erectors leave a portion of slot temporarily uncut to facilitate plumbing. After the flange and web welds are completed, the remainder of slot is cut. Short slotted holes in shear tab, if used, require more plumb-up work.

Bolting Standard

Welding

Fit-up Standard

Preheat Standard

Welding Notch tough electrode has slower deposition rates.
Removal of back-up bar, back gouging, and fillet reinforcing is all overhead work and labor intensive; however, the top flange back up bar does not require removal.
CJP weld of beam web to column requires significant additional welding.
Fillet weld of beam web to shear tab requires significant welding.

Sequencing Erector must follow patent holder's specified connection construction procedure.

Quality Control / Quality Assurance Fabricator must submit shop drawings to SSDA for approval.
See FEMA-350 and 353 for current QA recommendations.

2.14 BOLTED BRACKET (PROPRIETARY)

Patented cast steel brackets, supposedly available on the marketplace, make this connection proprietary. However, the authors could not locate the patent holder for such brackets. The authors added fabricated brackets to this *TIPS* because fabricated brackets are within the public domain.

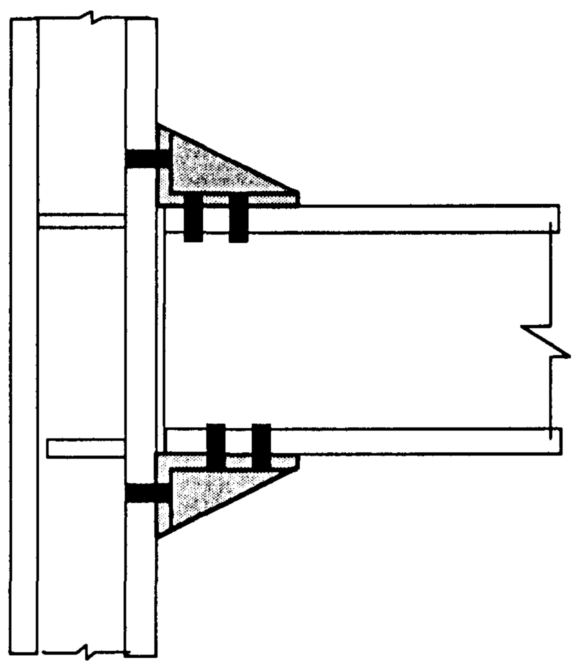


Figure 3-25 Bolted Bracket Connection

Reprinted from FEMA-350

Prequalification Data Considered

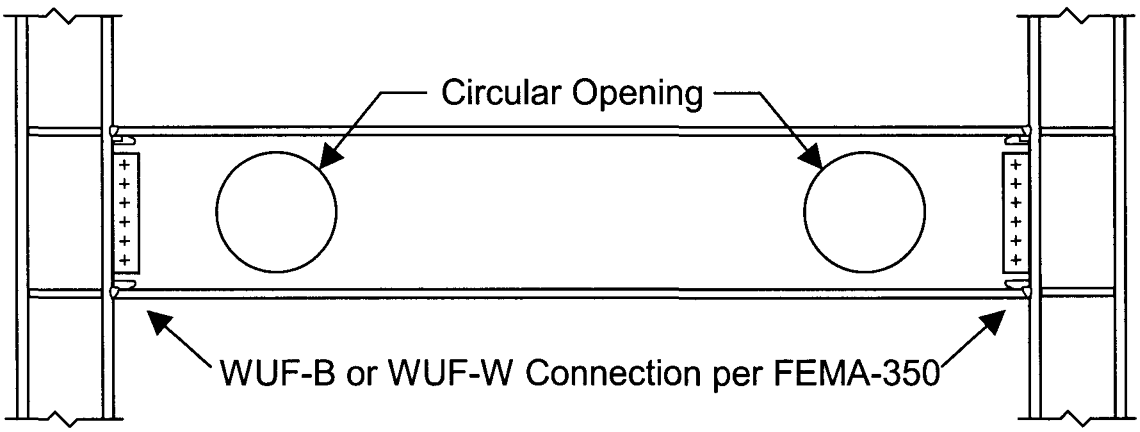
No known data.

2.14 BOLTED BRACKET (PROPRIETARY)

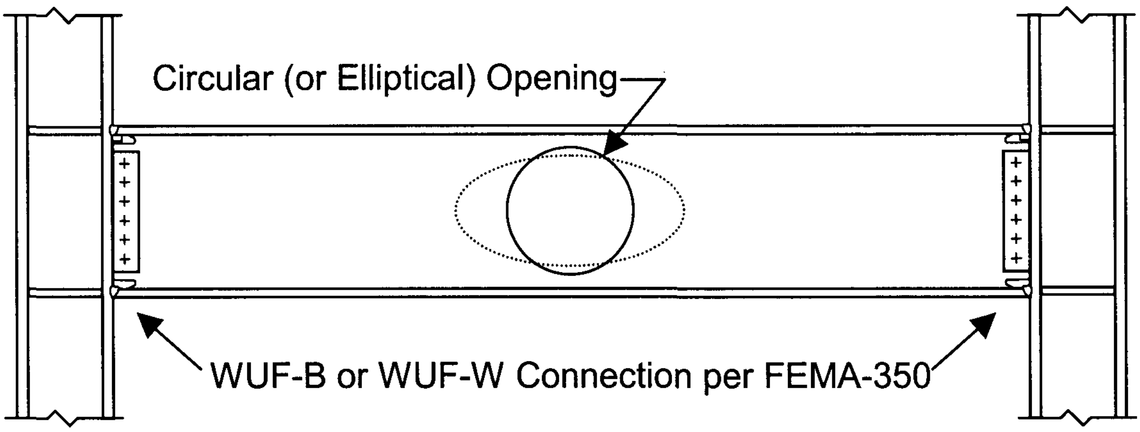
Cost Considerations

Material	Brackets add additional material.
Detailing	Additional detailing is required for brackets. Fit-up issues must be identified and detailed to suit. Consider the beam depth and out of square tolerances. Oversized holes should help.
Shop Fabrication	
Detail Parts	Brackets require additional fabrication.
Main Parts	Flanges of column and beams require drilling that must be precise. Automated equipment provides more precise and efficient fabrication. No weld access holes required on beams.
Fit-up	Bolt bottom bracket to column with fully tensioned bolts. Consider whether to attach top bracket or ship it loose.
Welding	Welds for continuity plates on columns and stiffeners on brackets need notch tough electrode with slower deposition rates.
Bolting	Bolt bottom bracket and furnish bolts for top bracket.
Shipping	Must allow for brackets.
Erection	
Unloading	Brackets require special care. May need to handle loose brackets.
Shakeout	Brackets take some additional deck space and cribbing; more blocking needed for shakeout.
Erection	Connectors must take care to bolt and pin bottom flange to prevent beam from tipping. Erector may need to consider adding a web plate.
Plumb-up	Standard size holes in bottom bracket and bottom beam flange set correct bay spacing. No weld shrinkage to consider.
Bolting	Oversize holes in top bracket facilitate hole alignment. Bolt sizes greater than 1 1/8 inch diameter require heavier equipment to fully tension.
Welding	No field welding.
Quality Control / Quality Assurance	Bolting quality control replaces welding quality control in field. See FEMA-350 and 353 for current QA recommendations.

2.15 REDUCED WEB (PROPRIETARY)



(a)



(b)

Reduced Web Section configurations: (a) dual opening and (b) single opening.

Reprinted with permission from Professor Aschheim. See Reference 12.

Prequalification Data Considered.

This connection is patented. Professor Mark Aschheim is the inventor and Programmatic Structures Inc., owned by Professor Aschheim, is the assignee. Professor Aschheim has tested various combinations of opening geometry and beam depth in combination with W14 columns under quasi-static reversed cyclic loading conforming to the SAC loading protocol.

2.15 REDUCED WEB (PROPRIETARY)

Cost Considerations

(For bolted web [WUF-B] or welded web [WUF-W])

Material Standard

Detailing Weld access holes and web openings require special detailing.
Welded web requires special detailing to suit erector.

Shop Fabrication

Detail Parts Standard
For welded web:
- Ends of column shear tabs require angled cuts adding labor to hand made plates.
- Column shear tabs require bevel preparation for weld to column.

Main Parts Weld access holes require special work for cutting and grinding to roughness within 500 micro inches.
Web openings on beams require additional work.

Fit-up Standard

Welding Weld for continuity plates and shear tabs on columns needs notch tough electrode with slower deposition rates.

Shipping Standard

Erection

Unloading Standard
Shakeout Standard
Erection Standard
Plumb-up Standard
Bolting Standard

Welding

Fit-up Standard for bolted web option.
For welded web:
- Tight fit-up of web to shear tab may require more bolts than determined for erection loads.
- Fit-up of web for CJP web weld can be difficult if fabrication is not correct.

Preheat Standard for bolted web.
CJP and fillet welds for welded web require additional preheat.

Welding Notch tough electrode has slower deposition rates. Removal of back-up bar, back gouging, and fillet reinforcing is all overhead work and labor intensive.
For welded web:
- Vertical CJP weld of beam web to column requires significant additional difficult welding.
- Skill level of welders and UT technicians are important factors to field production on these CJP welds.
- Non-fusible run-off tabs for web end weld require additional work in a cramped space.
- Fillet weld of beam web to shear tab requires significant additional welding.

Sequencing Standard for bolted web.
Special sequencing is required for welded web when considering preheat, restraint, and cooling of welds.

Quality Control / Quality Assurance See FEMA-350 and 353 for current QA recommendations.

3 COST CONSIDERATION SUMMARY

A GENERAL NOTE ON COST CONSIDERATIONS REGARDING WELDING QUALITY CONTROL AND QUALITY ASSURANCE

Brittle fractures experienced in the Northridge earthquake have increased the intensity of welding inspection with a corresponding increase in the cost of welded connections.

A review of Appendix 2 shows FEMA-353 recommendations: Complete joint penetration (CJP) groove welds require more costly ultrasonic testing (UT), and fillet welds require less costly magnetic particle testing (MT). Therefore, fabricators and erectors normally prefer fillet welded joints over groove welded joints. Additionally, UT testing brings up the following issues:

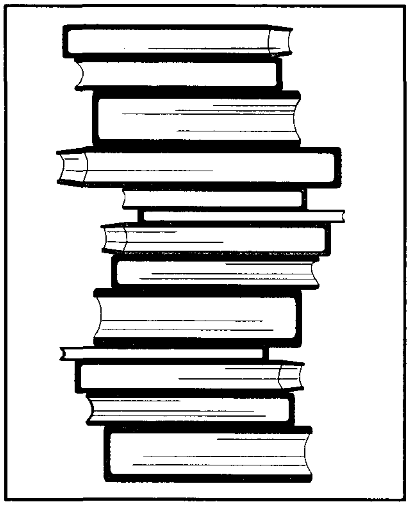
- The skill and training of the UT technician.
- The UT method used.
- The skill of the welder.
- The welder's methods and techniques.

CONNECTION COST COMPARISON SUMMARY

	Section Ref:	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10	2.11	2.12	2.13	2.14	2.15	2.15
	Conn. Abbrev.	WUF-B	WUF-W	FF	WFP	RBS (WELD WEB)	BUEP	BSEP	BFP	DST	WFP-ALT.1	WFP-ALT.2	DST-ALT.1	SLOTTED	BRACKET	RED. WEB (WUF-B)	RED. WEB (WUF-W)
TASK																	
MATERIAL		s	s	s	i	s	i	i	i	i	i	i	i	s	i	s	s
DETAILING		s	s	s	i	i	i	mi	i	mi	mi	i	i	i	i	i	i
SHOP	Detail Parts	s	i	i	i	s	i	mi	i	mi	i	i	mi	s	s	s	i
	Main Parts	i	i	i	s	mi	s	s	i	i	s	d	d	i	s	i	i
	Fit-up	s	s	s	i	s	i	mi	mi	i	i	i	i	s	s	s	s
	Welding	i	i	i	mi	i	mi	mi	mi	s	i	i	i	s	s	i	i
SHIPPING		s	s	s	i	s	i	i	i	s	s	s	i	s	s	s	s
ERECTION																	
	Unloading	s	s	s	s	s	s	s	i	s	i	I	s	s	s	s	s
	Shake-out	s	s	s	i	s	i	i	i	s	i	i	i	s	i	s	s
	Erection	s	s	s	i	s	mi	mi	i	i	i	s	i	s	s	s	s
	Plumb-up	s	s	i	d	s	i	i	d	s	s	d	s	i	d	s	s
	Bolting	s	s	s	s	s	mi	mi	mi	i	s	s	mi	s	i	s	s
	Weld Fit-up	s	i	s	i	i	0	0	0	0	s	d	0	i	0	s	i
	Weld Preheat	s	i	i	i	i	0	0	0	0	s	i	0	i	0	s	i
	Welding	i	mi	i	i	mi	0	0	0	0	i	i	0	i	0	i	mi
	Weld Seq.	s	i	i	i	s	0	0	0	0	i	i	0	i	0	s	i
QA/QC		i	i	i	i	i	s	i	i	i	i	i	i	i	s	i	i

0	No cost, task eliminated
d	Decreased cost from Pre Northridge (significant)
s	Same cost as Pre Northridge (or just a small increase or decrease)
I	Increase in cost from Pre Northridge (significant)
mi	Major increase in cost from pre Northridge

4. REFERENCES



1. AISC, (1992), *Manual of Steel Construction: Volume II Connections,* ASD/LRFD, First ed., American Institute of Steel Construction, Chicago.

2. AISC, (1994), *Manual of Steel Construction:* Load and Resistance Factor Design for Structural Steel Buildings, 2nd Edition, American Institute of Steel Construction, Chicago.

3. AISC, (April 15,1977), *Seismic Provisions for Structural Steel Buildings,* American Institute of Steel Construction, Chicago.

4. AISC, (November 10, 2000), *Seismic Provisions for Structural Steel Buildings, (1997) Supplement No.2,* American Institute of Steel Construction, Chicago.

5. Collin, A.L., and Putkey, J.J., (1999), "Welded Moment Frame Connections With Minimal Residual Stress," *Steel TIPS,* Structural Steel Educational Council, Moraga.

6. FEMA-350, (2000), *Recommended Seismic Design Criteria for New Steel Moment-Frame Buildings,* prepared by the SAC Joint Venture for the Federal Emergency Management Agency, Washington, DC.

7. FEMA-353, (2000), *Recommended Specifications and Quality Assurance Guidelines for Steel Moment-Frame Construction for Seismic Applications,* prepared by the SAC Joint Venture for the Federal Emergency Management Agency, Washington, DC.

8. Forell/Elsesser, (1995), "Steel Construction Update: Successful Test of Welded Steel Beam - Column Moment Connection," Forell/Elsesser Engineers, Inc., Structural Engineers, San Francisco.

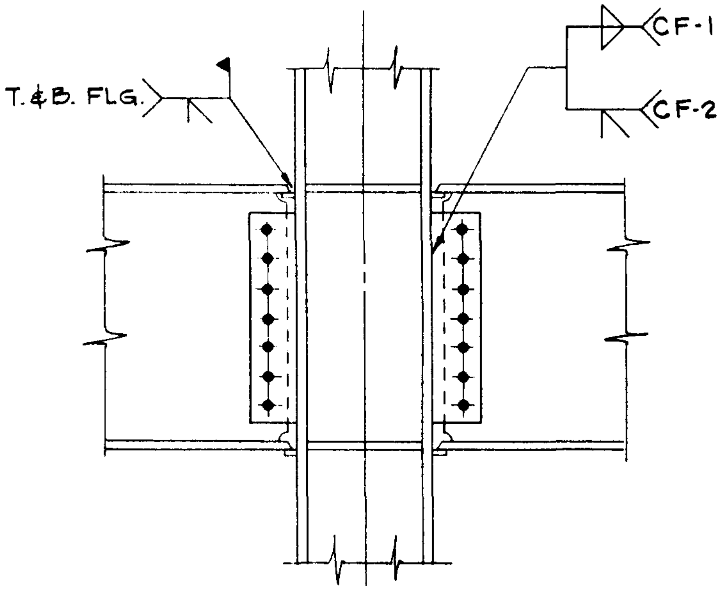
9. Popov, E.P and Takhirov, S.M., (2001), "Large Seismic Steel Beam-to-Column Connections," *Steel TIPS,* Structural Steel Educational Council, Moraga.

10. SSDA, (2002), *Slotted Web™ Connection Manual,* Seismic Structural Design Associates, Inc., Mission Viejo.

11. Steel Committee, (1986), "steel connections/details and relative costs," The Steel Committee of California, Walnut Creek and El Monte.

12. Halterman, A., and M.A. Aschheim (2002), "Reduced Web Section Beams: Experimental Findings and Design Implications," Proceedings of the 7th US National Conference of Earthquake Engineering, Boston, Massachusetts, July 21-25.

APPENDIX 1 - "PRE-NORTHRIDGE" CONNECTION



WEB BOLTED – FLANGE BUTT WELDED

▪▪▪CF—1▪▪▪	▪▪▪CF—2▪▪▪
Relative Cost	Relative Cost
1.00	1.06

For this category of connection, the beam-to-column moment connection CF-1 is the base Relative Cost Index 1.00 connection, with a single shear plate being fillet welded to the column flange. Beam flanges are fully welded to the column flange, providing a very ductile and economical moment connection. Attaching the shear tab to the column with a full penetration weld rather than a double fillet weld increases the relative cost 6%.

Reprinted from Steel TIPS, 1986. See Reference 11.

APPENDIX 2 - QUALITY ASSURANCE FOR PREQUALIFIED CONNECTIONS

FEMA WELD INSPECTION RECOMMENDATIONS

Reference:
FEMA 353 Part II
TABLE 5-3, 5-4

The following table summarizes requirements outlined by FEMA 353 and referenced in FEMA 350 PREQUALIFIED connection details:

CONNECTION	WELD	QA/OC CATEGORY	CATEGORY TABLE 5-3	INSPECTION TABLE 5-4	NOTES
2.1 WUF-B	Flange welds	AH/T	1	MT,UT 100% CJP's	NO REDUCTIONS
	Shear Tab weld	BL/T	3	UT 10% CJP's MT10% FILLETS	MT 6" SPOT RANDOM
2.2 WUF-W	Flange welds	AH/T	1	MT,UT 100% CJP's	NO REDUCTIONS
	Shear Tab weld	BM/T	2	MT 25% PJP's, FILLETS	FULL LENGTH
	Web End weld	BH/T	1	MT,UT 100% CJP's	REDUCTION APPLIES
	Web to Shear Tab weld	BL/L	3	MT 10% FILLETS	MT 6" SPOT RANDOM
2.3 FF	Flange welds	AHT	1	MT,UT 100% CJP's	NO REDUCTIONS
	Shear Tab weld	BH/T	1	MT,UT 100% CJP's	REDUCTION APPLIES
	Web End weld	BH/L	1	MT 25% FILLETS	PARTIAL LENGTH
	Web to Shear Tab weld	BH/L	1	MT 25% FILLETS	PARTIAL LENGTH
2.4 WFP	Flange Plate butt welds	AH/T	1	MT,UT 100% CJP's	NO REDUCTIONS
	Flange Plate side fillet welds	BH/L	1	MT 25% FILLETS	PARTIAL LENGTH
	Flange Plate end fillet welds	BH/T	1	MT 25% FILLETS	FULL LENGTH
	Shear Tab weld	BH/T	1	MT 25% FILLETS	FULL LENGTH
	Web End weld	BM/T	2	MT 25% PJP's	FULL LENGTH
	Web to Shear Tab weld	BH/L	1	MT 25% FILLETS	PARTIAL LENGTH
2.5 RBS-WW	Flange welds	AH/T	1	MT.UT 100% CJP's	NO REDUCTIONS
	Shear Tab weld	BM/L	2	MT 25% FILLETS	PARTIAL LENGTH
	Web End weld	BM/L	2	MT,UT 100% CJP's	PARTIAL LENGTH
RBS-BW	Flange welds	AH/T	1	MT.UT 100% CJP's	NO REDUCTIONS
	Shear Tab weld	BL/T	3	UT 10% CJP's MT10% FILLETS	MT 6" SPOT RANDOM

2.6 BUEP	Flange welds	AH/T	1	MT,UT 100% CJP's	NO REDUCTIONS
	Web weld	BM/L	2	MT 25% FILLETS	PARTIAL LENGTH
2.7 BSEP	Flange welds	AH/T	1	MT,UT 100% CJP's	NO REDUCTIONS
	Web weld	BM/L	2	MT 25% FILLETS	PARTIAL LENGTH
	Stiffener weld to beam	BM/L	2	MT,UT 100% CJP's	PARTIAL LENGTH
	Stiffener weld to end plate	AH/T	1	MT,UT 100% CJP's	NO REDUCTIONS
2.8 BFP	Flange Plate butt welds	AH/T	1	MT,UT 100% CJP's	NO REDUCTIONS
	Shear Tab weld	BM/L	2	MT 25% FILLETS	PARTIAL LENGTH
2.9 DST	NO WELDING				
ALL	CONT'Y PLATES				
	Flange Welds	BM/T	2	MT, UT 100% CJP's	REDUCTION APPLIES
	Web Weld	BL/L	3	MT 10% PJP's, FILLETS	MT 6" SPOT RANDOM
ALL	DOUBLER PLATE				
	All welds	BL/L	3	MT 10% PJP's, FILLETS	MT 6" SPOT RANDOM

<u>NOTE:</u>

REDUCTION: **REDUCE INSPECTION TO 25% IF REJECTION RATE IS LESS THAN 5% AFTER 40 WELDS FOR A GIVEN WELDER**

PARTIAL LENGTH: **FOR WELDS OVER 24 INCHES LONG, TEST 6 INCHES ON EACH END AND 6 INCHES ALONG THE LENGTH AT STARTS & STOPS**

About the Authors

Patrick M. Hassett received his Bachelor's degree in Civil Engineering in 1983, and a Master's degree in Structural Engineering and Structural Mechanics in 1985 from The University of California at Berkeley. He is a licensed Civil and Structural Engineer in California and is also licensed in Illinois and Missouri. He has fifteen years experience in the fabrication and erection of major structural steel construction projects. He is a member of SEAONC, and ASCE, is past chairman of the Structural Steel Educational Council, has served on the SAC Joint Venture Project, and currently serves on the AISC Seismic Design committee.

He is currently running his own consulting firm in Castro Valley, California, primarily serving the engineering needs of steel fabricators and erectors. Among his recent projects is the connection design and erection engineering on the 54-story Torre Mayor Tower in Mexico City. More recently, he engineered the steel erection procedure on the Walt Disney Concert Hall in Los Angeles.

James J. Putkey is a Consulting Civil Engineer in Moraga, California. He received a Bachelor of Civil Engineering degree from the University of Santa Clara in 1954. After two years in the U.S. Army, 19 years with the Erection Department of Bethlehem Steel Corporation—Pacific Coast Division, and seven years with the University of California—Office of the President, he started his own consulting business. He has provided consulting services to owners, contractors, attorneys, and steel erectors for the past 20 years.

Mr. Putkey is now "Semi-Retired." He serves as a hearing officer for the University of California-Office of the President, and occasionally writes or helps write Steel TIPS.

List of Published Steel *TIPS**

June 02: Use of Deep Columns in Special Steel Moment Frames, by Jay Shen, Abolhassan Astaneh-Asl and David McCallen.
May '02: Seismic Behavior and Design of Composite Steel Plate Shear Walls, by Abolhassan Astaneh-Asl.
Sept '01: Notes on Design of Steel Parking Structures Including Seismic Effects, by Lanny J. Flynn, and Abolhassan Astaneh-Asl.
Jun '01: Metal Roof Construction on Large Warehouses or Distribution Centers, by John L. Mayo.
Mar. '01: Large Seismic Steel Beam-to-Column Connections, by Egor P. Popov and Shakhzod M.Takhirov.
Jan '01: Seismic Behavior and Design of Steel Shear Walls, by Abolhassan Astaneh-Asl.
Oct. '99: Welded Moment Frame Connections with Minimal Residual Stress, by Alvaro L. Collin and James J. Putkey.
Aug. '99: Design of Reduced Beam Section (RBS) Moment Frame Connections, by Kevin S. Moore, James O. Malley and Michael D. Engelhardt.
Jul. '99: Practical Design and Detailing of Steel Column Base Plates, by William C. Honeck & Derek Westphal.
Dec. '98: Seismic Behavior and Design of Gusset Plates, by Abolhassan Astaneh-Asl.
Mar. '98: Compatibility of Mixed Weld Metal, by Alvaro L. Collin & James J. Putkey.
Aug. '97: Dynamic Tension Tests of Simulated Moment Resisting Frame Weld Joints, by Eric J. Kaufmann.
Apr. '97: Seismic Design of Steel Column-Tree Moment-Resisting Frames, by Abolhassan Astaneh-Asl.
Jan. '97: Reference Guide for Structural Steel Welding Practices.
Dec. '96: Seismic Design Practice for Eccentrically Braced Frames (Based on the 1994 UBC), by Roy Becker & Michael Ishler.
Nov. '95: Seismic Design of Special Concentrically Braced Steel Frames, by Roy Becker.
Jul. '95: Seismic Design of Bolted Steel Moment-Resisting Frames, by Abolhassan Astaneh-Asl.
Apr. '95: Structural Details to Increase Ductility of Connections, by Omer W. Blodgett.
Dec. '94: Use of Steel in the Seismic Retrofit of Historic Oakland City Hall, by William Honeck & Mason Walters.
Dec '93: Common Steel Erection Problems and Suggested Solutions, by James J. Putkey.
Oct. '93: Heavy Structural Shapes in Tension Applications.
Mar. '93: Structural Steel Construction in the '90s, by F. Robert Preece & Alvaro L. Collin.
Aug. '92: Value Engineering and Steel Economy, by David T. Ricker.
Oct. '92: Economical Use of Cambered Steel Beams.
Jul. '92: Slotted Bolted Connection Energy Dissipaters, by Carl E. Grigorian, Tzong-Shuoh Yang & Egor P. Popov.
Jun. '92: What Design Engineers Can Do to Reduce Fabrication Costs, by Bill Dyker & John D. Smith.
Apr. '92: Designing for Cost Efficient Fabrication, by W.A. Thornton.
Jan. '92: Steel Deck Construction.
Sep. '91: Design Practice to Prevent Floor Vibrations, by Farzad Naeim.
Mar. '91: LRFD-Composite Beam Design with Metal Deck, by Ron Vogel.
Dec. '90: Design of Single Plate Shear Connections, by Abolhassan Astaneh-Asl, Steven M. Call and Kurt M. McMullin.
Nov. '90: Design of Small Base Plates for Wide Flange Columns, by W.A. Thornton.
May '89: The Economies of LRFD in Composite Floor Beams, by Mark C. Zahn.
Jan. '87: Composite Beam Design with Metal Deck.
Feb. '86: UN Fire Protected Exposed Steel Parking Structures.
Sep. '85: Fireproofing Open-Web Joists & Girders.
Nov. 76: Steel High-Rise Building Fire.

* The Steel TIPS are available at AISC website: www.aisc.org, and can be downloaded free for personal use as a courtesy of the California Field Iron Workers Administrative Trust and the AISC.

STRUCTURAL STEEL EDUCATIONAL COUNCIL

P.O. Box 6190
Moraga, CA 94570
Tel. (925) 631-1313
Fax. (925) 631-1112

Fred Boettler, Administrator

Steel TIPS may be viewed and downloaded at www.aisc.org

S P O N S O R S

Adams & Smith
Bannister Steel, Inc.
Bethlehem Steel Corporation
Bickerton Industries, Inc.
Bostrom Bergen
California Erectors
Eagle Iron Construction
Eandi Metal Works
Four Star Erectors
Gayle Manufacturing
The Herrick Corporation
Junior Steel Corporation
Martin Iron Works, Inc.
McLean Steel Inc.
Nelson Stud Welding Co.
Oregon Steel Mills
Plas-Tal Manufacturing Co.
Reno Iron Works
SME Industries
Shollenbarger-Borello, Inc.
Strocal Inc.
Templeton Steel Fabrication
Trade Arbed
Verco Manufacturing, Inc.
Vulcraft Sales Corp.
Western Steel & Metals, Inc.

The local structural steel industry (above sponsors) stands ready to assist you in determining the most economical solution for your products. Our assistance can range from budget prices and estimated tonnage to cost comparisons, fabrication details and delivery schedules.

Funding for this publication provided by the California Field Iron Workers Administrative Trust.