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# Tips for Reducing Connection Costs

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A little planning goes a long way, especially with respect to steel connections. These helpful tips should help you keep bolts from driving you nuts, and welds from torching your temper.

Connections can be expensive, and they can take a lot of effort to create during the design and construction process. How can you save time and money—and make everybody’s work easier when working with connections on fast-track schedules? Here are some general guidelines for structural engineers for the design of economical bolted and welded connections for columns, beams and braces.

1. Communication is key. Develop a working design-build team for fast-track projects—with the fabricator and erector on board. The main benefits are:

- Design requirements can be conveyed accurately.
- Everyone’s expertise can be utilized.
- Detailing can start quickly.
- Duplication of work can be avoided.
- “Revise and Resubmit” on approvals is avoided.
- All parts work together without “surprises.”
- Paperwork is minimized.
- Your best chance for cost savings.
- Good working environment.

2. Connection approvals should occur in a timely manner. Detailers need connections immediately for fast-track project delivery. Make approval comments clear. Confusing notes cause misinterpretation and more paperwork.

3. Engineers should always provide all end reactions, including shear, moment, torsion and axial end reac-

tions. Drawings that don’t show actual end reactions can lead to costly and unsafe connections.

4. Always provide complete load paths (including transfer forces) where there are axial forces. Keep load paths simple.

5. Favor factored end reactions (LRFD) over service end reactions (ASD).

6. Provide details that clearly represent the design intent. They will eliminate misunderstandings and save time.

7. Use standard AISC connections when possible.

8. Don’t be excessively conservative—connections need to withstand only design loads.

9. Simplify as much as possible. For example, make column-base details symmetrical, use the same spacing for expansion anchors and minimize the number of sizes of slab edge closures/pour-stops. This expedites the fabrication and erection process and greatly reduces the number of possible mistakes—and repair costs.

10. Check structural drawings for constructability issues.

11. Review the member sizes for connection economy:

- Preferably, a *supporting* beam should have at least the same depth as the *supported* beam.
- Don’t frame W8 beams into the webs of heavy W-shapes or plate girders. The thick flanges of the heavier shapes will require exces-

sive—and sometimes impossible—copies in the W8.

■ Favor W12 and W14 sections for typical gravity columns. The distance between flanges makes web connections easier.

■ Consider using heavier member sizes to eliminate stiffeners (see Tip 18).

■ Provide adequate flange width at perimeter members. Provide beams that frame slab openings to support deck and pour stops, and to weld studs.

12. Use A36 steel for connection angles, and plates for typical connections.

13. Specify readily available anchor rods. Often, the rods are delivered in a rush immediately after the contract has been awarded and before communication has been established between fabricator and engineer.

14. When possible, use standard tolerances established by ASTM A6/A6M, the AISC *Code of Standard Practice for Steel Buildings and Bridges* ([www.aisc.org/code](http://www.aisc.org/code)), and AWS. Tighter tolerances will increase costs and construction time substantially.

15. Avoid overly restrictive specifications.

16. Don’t “over-specify” details—you might not be aware of fabrication/erection procedures, required clearances, etc.

17. Moment connections:

- Eliminate when possible. For example, you can use a cantilever at the

## Least Weight Isn't Always Least Cost

- roof in lieu of two moment connections to the column.
- Provide actual moments/moment envelopes and vertical end reactions.
- Favor extended end-plate moment connections. Refer to AISC *Design Guide 4: Extended End-Plate Moment Connections* for design information.
- Shop weld short cantilevers.
- Moment connections to HSS columns are usually very expensive.
- 18.** Stiffeners can complicate connections for framing beams.
  - Specify only when required.
  - Wherever possible, use partial-depth stiffeners.
  - AISC's SteelTool™ *Clean Columns v3.1* can help avoid column stiffeners. It's available at [www.aisc.org/steeltools](http://www.aisc.org/steeltools).
  - Refer to AISC *Design Guide 13: Wide-Flange Column Stiffening at Moment Connections* for designing and specifying stiffeners.
- 19.** Favor one-sided shear connections (single-angle and single-plate), but avoid expensive through-plate connections at HSS columns.
- 20.** Rule of thumb: The more pieces there are in a connection detail, the more expensive it is to fabricate and erect.
- 21.** Give some thought to the design of column splices:
  - Do not specify to "develop the full bending strength of the smaller shaft." This is not always necessary.
  - Use field-bolted column splices for moderate uplift forces.
  - Minimize the number of splices, especially for HSS columns. Sometimes it is more economical to extend the lower shaft for another level than to add a splice.
  - For W-column splices with PJP or CJP welds at flanges, favor web channel(s) over temporary flange lugs wherever possible. This will make detailing, fabrication and erection easier.
- 22.** Design-build projects require extra attention:

## Heavier Columns Minimize Stiffeners

- Complete each released area as much as possible.
- Size members conservatively.
- Consider using field-welded connections for openings.
- Immediately inform fabricator of the areas of possible substantial revisions.
- 23.** Provide for tolerances—use oversized, short-slotted, and long-slotted holes in bolted connections, and leave extra space for welded connections.
- 24.** Make embedded plates a minimum 6" to 8" larger than required for connections. Field fixes for embedded plates that are mislocated are time and money consuming.
- 25.** Clearly identify all changes and revisions on design drawings.
- 26.** When shop or field errors require correction:
  - Request an as-built report. It clearly shows the problem and eliminates misunderstanding and misinterpretation.
  - Discuss possible solutions with fabricator or erector.
  - Keep in mind: labor is expensive, material is relatively inexpensive.
  - As a rule of thumb, fast decisions and approvals are required to continue the work.
  - Remember that not every error requires correction.
- 27.** Wherever possible, specify bearing joints. It makes the most economical use of bolts, eliminates masking or a special paint system, and reduces installation and inspection requirements.
- 28.** Use snug-tightened joints as much as possible.
- 29.** Favor ¾"-diameter A325 bolts for typical structures.
- 30.** Try to limit bolt diameters to 1" or smaller. Larger diameters require special equipment, larger spacing and edge distance, and special 5/16"-thick washers (ASTM F436) for fully pretensioned ASTM A490 bolts.

## Specify ASTM A36 Connection Material

- 31.** Never use bolts with the same diameter but different strengths on a job—it can lead to mistakes.
- 32.** Use short-slotted holes in outstanding legs of connection angles, end plates and single-plate connections.
- 33.** When loads are large, consider larger diameter bolts and/or ASTM A490 bolts.
  - Bolt material cost is roughly proportional to strength.
  - Higher strength bolts save in connection material, hole making, and installation cost.
- 34.** Consider excluding bolt threads (X-bolts) for:
  - Heavily loaded connections where typical bolt size doesn't give enough capacity.
  - Shop assembled trusses.
  - Connections when outer plies are 3/8" thick or larger.
- 35.** Use slip-critical connections for:
  - Bracing connections with oversized or slotted holes.
  - Field-assembled trusses with oversized holes.
  - Members with short/long-slotted holes when force applies parallel to the slots.
  - Built-up compression members.
  - Cyclic loads.
- 36.** Where fully pretensioned bolts are needed, permit the use of any of the four methods approved by RCSC and AISC:
  - Turn-of-nut.
  - Calibrated wrench.
  - Twist-off-type tension-control bolt.
  - Direct-tension-indicator.
- 37.** Mechanically galvanized ASTM A325 bolts provide excellent corrosion resistance and require a minimum overlapping of nuts and easier pretensioning.
- 38.** Keep your bolt holes as rational as possible:
  - Don't use different hole sizes in the same member. It leads to mistakes

## Keep Bolt Holes One Size Per Piece

- and slows fabrication because shop re-tooling is required for the piece.
- Don't specify slots in material thicker than bolt diameter plus  $\frac{1}{8}$ ". The AISC *Specification* doesn't allow punching holes in such material, and it is difficult to make slots. A good alternative would be to use oversized holes.
  - Use the same oversized holes in all plies if it is possible.
  - Use long-slotted holes in girts and any members that must be field-aligned to tolerances other than standard steel framing tolerance (for example, curtain wall connections).
- 39.** Correctly apply AISC requirements for fillers:
- Fillers in slip-critical joints are not required to be developed.
  - Fillers up to  $\frac{1}{4}$ " thick can be used in bearing joints without reduction in strength.
  - Fillers up to  $\frac{3}{4}$ " thick don't have to be developed if the design shear strength of the bolts is multiplied by the factor  $[1 - 0.4(t - 0.25)]$ , where  $t$  is the total thickness of the fillers up to  $\frac{3}{4}$ ".
  - Fillers over  $\frac{3}{4}$ " must be developed by bolts or welds, in or outside of the joint.
- 40.** Leave extra holes open. In almost all cases they don't need to be filled, and filling takes a lot of time (think labor costs), especially for thick members.
- 41.** Avoid over-welding.
- The weld doesn't need to be stronger than base metal in any case.
  - Excessive welding can cause serious problems (distortion, cracking, etc.). This can lead to expensive repairs or even rejections.
  - Weld connection elements for actual forces.
- 42.** Use single-pass fillet welds where possible. A  $\frac{3}{8}$ " fillet weld requires 44% more material and 100% more labor, but it is only 20% stronger than a  $\frac{5}{16}$ " fillet weld.
- 43.** Use AWS D1.1 rules for minimum weld size. Per AWS D1.1/D1.1M:2002, Table 5.8, for low-

## Member Reactions Simplify Detailing

- hydrogen process: "Minimum weld size is dependent upon the thinner of the two parts joined."
- 44.** Use intermittent fillet welds when possible.
- 45.** Use AISC *Specification* Appendix J2.4 for fillet welds. This allows an increase in strength of the fillet weld based on direction of the force. *Note: Per AISC it is also acceptable for extended end-plate moment connections.*
- 46.** Favor fillet welds over groove welds. Groove welds are usually more time consuming.
- 47.** Favor PJP welds over CJP welds.
- 48.** Allow full-strength connections in lieu of CJP welds in statically loaded structures. Fillet welds up to  $\frac{3}{4}$ " are more economical.
- 49.** Specify effective throat size or required strength for welds.
- 50.** Allow the use of groove-welded joints with a preparation that minimizes weld metal volume.
- 51.** Leave weld access holes open.
- 52.** Inspect critical CJP welds with Ultrasonic Testing (UT).
- 53.** Avoid the "weld-all-around" symbol. It is expensive, and in a lot of cases it's not required—and sometimes it's even prohibited.
- 54.** Avoid shop welding on galvanized surfaces.
- 55.** Layout welds to reduce restraint, especially for large welds. This lowers the possibility of lamellar tearing.
- 56.** Favor horizontal and flat positions. Let gravity work for you.
- 57.** Try to minimize field-welded connections and favor field-bolted connections. ★

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## Single-Pass Fillets Are Cost-Effective

### Favor Fillet Welds Over Groove Welds

### Slip-Critical Joints Only When Needed