# 59 Tips & More for economical design

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**MSC surveyed six fabrication engineers to find out what designers can do to make their projects more economical.** Our participants were eager to weigh in on just about every topic, from connection details to business practices. But it all boils down to this: Every engineering design has to be fabricated, and paying attention to constructability pays off for everyone involved—in a big way—in the long run.

## WELDS

**Avoid over-welding:**

- A weld never needs to exceed the connected part strength.
- Excessive welding can cause serious problems (distortion, cracking, etc.). This can lead to expensive repairs or even rejections.
- Design welds for connection elements for actual forces.
- The larger a weld, the larger its carbon footprint—and the more emissions it creates.

**Avoid all-around welding** when not required. Gravity columns to base plates should rarely need welding all around. Normally welding one side of the web, the outside of one flange, and the inside of the other flange is sufficient.

**Select fillet welds** over partial-penetration groove welds when possible. Select partial-penetration groove welds over full-penetration groove welds when possible. Small and long fillet welds are more economical than large and short welds.

**Keep weld sizes** at 5⁄16 in. or less for fillet welds (accommodates a single pass); increase length if needed.

**For vertical brace connections,** match the weld length to the available gusset plate length. Since weld strength is proportional to weld size, but volume of weld metal (the true indicator of weld cost) is proportional to the square of the weld size, use a longer smaller weld if possible. Make as many of the connections the same as possible.

## BOLTS

**X bolts** work in most connections. Where connection material is greater than 3⁄8 in. thick or where the head of the bolt is on the thin side, the thread will not be in the shear plane. So use the strength that is available.

**Specify bearing bolted joints,** rather than slip critical (SC) joints, whenever possible. It makes the most economical use of bolts, eliminates masking or special paint systems, and reduces installation and inspection requirements. Avoid general statements about using SC bolts; carefully consider their use.

**Don't just fill up** beam webs with bolt rows. Use the appropriate number of rows for strength requirements.

**Provide for tolerances.** Use oversized, short-slotted, and long-slotted holes in bolted connections if permitted, and leave extra space for welded connections.

## WHO WE SURVEYED

**Gary Violette, P.E.,** President, VSE, Inc., Windsor, Conn.

**W. Steven Hofmeister, P.E., S.E.**, Principal, Thornton Tomasetti, Kansas City

**Saul Mednick,** Chief Engineer/General Manager, Globe Iron Construction Company, Inc., Norfolk, Va.

**Tony C. Hazel, P.E.**, Senior Structural Engineer, Ferrell Engineering, Birmingham, Ala.

**Ron Meng, P.E.,** Chief Engineer, Lynchburg Steel, Monroe, Va.

**Victor Shneur, P.E.,** Chief Engineer, LeJeune Steel Company, Minn.

# DRAWINGS

**Avoid the use** of the terms "typical" and "similar" on design drawings. When "typical" is used, note where it applies—which column lines, which levels, etc. If a section is "similar" to another, what is different about it versus what is the same? What the designer intends is not necessarily what we see.

**Avoid vague terms** that may have many definitions, such as "design for full capacity."

**Always show** the extent of each section. Where does one section change to another section? Do they turn corners?

**Always dimension plans** at every level and to the greatest extent possible. Too often we see dimensions on the foundation plan, only to find none at upper floors or elevation and bracing views. We hear the excuse that when the architect changes things, it is too difficult to find and correct all of the dimensions. However, the risk for error is there for someone else who constantly has to transfer this information. It is also very cumbersome to build by.

**Provide complete drawings** that are coordinated and reviewed by both engineer and architect prior to release. Often, the two sources do not coordinate edge-of-slab dimensions, which are critical to efficient detailing without having to submit RFIs. The later information is received, the more it affects (increases) time and cost.

**Complete the structural design** to the greatest extent possible, coordinating the structural drawings with the architectural drawings, and show all structural steel on the structural drawings.

**Clearly indicate seismic requirements** on drawings; for $R > 3$, provide the extent of seismic design or detailing desired in connections to match the response used in the design model. AISC's *Seismic Provisions* provide guidance for information on drawings.

**At curved walls,** provide arc radius and ordinate location for the center point of each arc; provide an X-Y coordinate for all column locations.

**Update drawings** after numerous (substantial) "sketch" or "addendum" changes have been made.

**Size welds** or provide adequate loads for determination of weld schemes required.

**Always provide all end reactions,** including shear, moment, torsion and axial end reactions. Drawings that don't show actual end reactions can lead to costly and unsafe connections.

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

**Specify actual forces** for splices when possible; don't specify that braced and moment frame column splices should develop the full tensile or bending strength of the upper shaft. Developing the full tensile or bending strength requires very expensive field splices, often with complete joint penetration welds. Due to typical splice locations and the presence of compressive forces, it is an extremely rare case when full tensile or bending strength needs to be developed.

**In the case of tensile forces,** don't size the members (braces, truss chords, etc.) based on only the gross section. The effective net section may control and require costly reinforcement. Size tension members based on the gross and the effective net section, staying on the conservative side when the actual connection design is unknown.

**Simplify as much as possible.** For example, make column-base details symmetrical and use the same spacing for expansion anchors. This expedites the fabrication and erection process and greatly reduces mistakes and repair costs.

**Don't over-specify connections.** If you don't design the connections on your drawings, you should at least provide actual and complete forces. If the sets of load combinations and connection performance criteria (or architectural constraints) are too complicated to communicate to the steel contractor, then design the connections on your drawings (and enlist the contractor's assistance to verify constructability).

**Do not specify** moment connections as "full moment capacity." The first RFI you will receive if you do this is, "What is full moment capacity?" (i.e., is it compact or slender?) Real structures normally do not utilize the full moment capacity of very many members, and specifying such will almost certainly require member end supplement plates if you are using bolted construction.

# CONNECTIONS

**Use single-sided connections,** shear tabs, or single angles wherever possible.

**Orient columns** in moment frames so that moment connections are to the column flanges whenever possible.

**Show connection concepts** in sufficient realistic detail to accurately depict what the finished connection may look like.

**Make embedded plates** a minimum 6 in. to 8 in. larger than required for connections as a rule of thumb. Field fixes for embedded plates that are mislocated are time-consuming and expensive.

**Avoid cambering moment and braced frame girders.** This complicates the connections and adds cost. Keep in mind that these connections provide end restraint and reduce deflection.

**Rule of thumb:** The more pieces there are in a connection detail, the more expensive it is to fabricate and erect.

**Do not over-economize connections.** If the overall connection configuration is virtually the same, reducing the amount of weld or bolt count in a single non-repetitive connection, by even a large percentage (e.g., in excess of 25% to 30%), will probably increase the overall time and expense of the project. Repeating connections will reduce connection design, detailing, layout, fabrication, and erection costs due to the reduced learning curve.

# BUSINESS

**Someone once said** that "The most expensive part of the job is cheap detailing." Paying a little more for someone that does quality detailing is almost always worth the extra expense through savings in fabrication and erection problems.

**The elephant in the room** is that your reputation precedes you. Unreasonable requirements on previous jobs will affect the bid price on the next project.

**Develop a relationship** with one or two fabricators who you can call to discuss ideas with before you go out to bid.

**Understand the fabrication process.** Ask the fabricator for a plant tour.

# CODES & SPECS

**Choose one specification** and one specification only! Do not state that a structure's gravity system connections are to be designed to ASD, then indicate the lateral system as LRFD, or visa versa. Have all systems adhere to either code, but not both.

**Understand the seismic codes** and indicate your requirements in detail on the structural steel design drawings. Do not simply specify a code then leave it to others to interpret your intent.

**Select an *R* of 3** or less whenever possible. When R > 3 the AISC *Seismic Provisions* must be applied, which has a significant associated cost implication.

**When possible, use standard tolerances** established by ASTM A6/A6M, the AISC *Code of Standard Practice for Steel Buildings and Bridges* and AWS. Tighter tolerances will increase costs and construction time substantially.

# COMMUNICATION

**Advise the fabricator** when a change is coming and indicated the areas affected by any change. The designer and detailer can "work around" them and not waste valuable time and money when a change will undo all that is being designed/detailed.

**Call or visit** a local fabricator to determine steel shape availability prior to final member design as well as feasibility for unusual design concepts.

**Follow the design sketches** provided by the connection engineer. If you have questions or a conflict exists, discuss them with the connection design engineer before making any changes.

**Provide "checked" drawings** to the maximum extent possible at time of approval. If unchecked at approval, provide checking while the drawings are out for approval and ready for induction into the fabrication shop if nothing is marked during approval.

# QUIPS

**As a designer,** realize that what your professors taught you is only about 1% (maybe .9% for a B.S. and 1.1% for a Ph.D.) of what you really need to know. The good news is that you have about 40 years to learn the rest.

**Learn to visualize** what you are analyzing and designing (one of the greatest and possibly most underrated benefits of BIM). Find steel fabricators, erectors, and detailers that you can trust and can work with. They will provide tremendous guidance towards acquiring the rest of that 99% that we need to know about the buildings we design.

# SAGE ADVICE

**A beam, column,** or brace connection is not just a dot on a screen with three thin lines approaching it. Moreover, the connection does not care if you used method of sections, method of joints, stiffness method, finite element, Chapter C design, or a simplified rational method. In a large structure, it might be larger than 4 ft by 4 ft, weigh more than a ton, and require 50 shop hours for layout and fabrication and another 25 field man-hours to assemble. It might even be too big to ship!

**If you are** an East Coast designer that has been taught to delegate connection design to the contractor, do not be afraid to fully design, or even detail, complicated connections. Steel contractors do not make any more money writing RFIs than designers make answering them. Be clear, be complete. However, this does require that, as a designer, you possess an adequate understanding of fabrication and erection. Remember that an ironworker's heavy winter Carhart coat, gloved hands, and TC wrench will require more room than usual to access bolts.

**Think about the** steel contractor's estimator. You may have had several months to conceive, analyze, and design the structure, and to (hopefully) coordinate it with the architect and other consultants. The estimator may have as little as four to five weeks to receive and print drawings, assess quantities of main and secondary members, and obtain quotes from deck, joist, and paint/galvanizing suppliers. Make your drawings user-friendly. Very few responsible steel contractors will actually "bid what they see and change-order what they don't understand," particularly when they are engaged early in the project (although the designer in me feels compelled to add that a few bad apples can make the whole bunch stink). Do not fill your drawings and specs with boilerplated information.

# MODELING

**Conduct a physical (model) review** of your structure to eliminate interferences and identify multi-connections to columns. The typical "cartoons" don't help when the skews are 20° and not the 45° shown on sections.

# PAINTING

**Specify paint for** only those items that really need it. In a typical building, the steel within the vapor barrier that is not exposed to view should not need paint at all, fireproofed or otherwise. Save the painting for steel that is in a truly agressive or outdoor atmosphere, or that is exposed to view.

**Provide clear, thorough paint schemes** for locations of application. Paint notes of "everywhere except where fireproofed" don't really help. "If exposed" isn't always clear when studying structural and/or architectural drawings. Don't make the fabricator guess or have to rely on architectural drawings.

# MEMBER SELECTION

**When showing stiffeners** or other plate material, use popular flatbar sizes and UM plate sizes (usually 3⁄16-in., ¼-in., 5⁄16-in., ½-in., 5⁄8-in., ¾-in., and 1-in. thicknesses and widths of 1 in. through 6 in., 8 in., 10 in., and 12 in.). Bars make more sense than handling a 96-in. by 20-ft plate just to cut a few fittings. Also, avoid extremely large and thick angle sizes when dealing with a small amount of fittings.

**Use WTs sparingly** unless several will be used. Splitting a wide-flange shape is expensive, and it may warp. There is always the issue of kerf (material lost due to the width of the cutting flame if oxyfuel is used in the cutting process). If trusses are being fabricated, WTs may be useful, especially for painting (as opposed to double-angle or similar chords), but keep in mind that web extensions, which are often required, are very expensive.

**Least weight** is *not* always least cost!

- Select member sizes with sufficient depth to provide reasonable connections. For example, use a W16×26 rather than a W14×22, especially if the member is coped.
- Use heavier columns to eliminate stiffener plates and/or web doubler plates at moment connections.
- Standardize member sizes as much as possible. Steel may often be purchased at lower costs in bulk quantities. If a mill order is required, there may be a minimum order.
- Do not reinforce beam web penetrations if not absolutely necessary.

**Avoid expensive through plates** at HSS column connections when possible. Favor one-sided shear connections (single-plate and single-angle).

**When specifying beam camber,** don't specify less than ¾ in. camber.

**Review member sizes** for connection economy:

- Preferably, a supporting beam should have at least the same depth as the supported beam.
- Favor W12 and W14 sections for typical gravity columns. The distance between flanges makes web connections easier.
- Provide perimeter beams with adequate flange width to support any deck and pour stops, and to allow for welding studs.

# YOUR TIPS

**Do you have any thoughts on these tips** or suggestions of your own that you'd like to add? We'd like to hear from you! Go to www.modernsteel.com, click on Reader Feedback, and post your comments in our Reader Forum. MSC