An Ounce of Prevention

By James M. Fisher Ph.D., P.E. and Lawrence A. Kloiber, P.E.

Here are a few helpful tips for avoiding (and fixing) common design, fabrication and construction problems.

When designing, fabricating and erecting a steel frame, common problems usually can be fixed with simple solutions. Attendees at this spring's continuing education seminar on field fixes (also presented at the North American Steel Construction Conference in March) picked up numerous tips and tricks for avoiding—and fixing—design and construction problems. Here are some highlights of what they learned.

There's a problem—now what?

When alerted to a problem in the field, the first thing to do is get a complete description of the situation. Visual information is essential to evaluate the problem, so ask for a drawing, sketch or photo. Discuss the problem and potential fixes with the general contractor, erector and/or fabricator. All involved parties should act quickly to resolve problems, since quick resolutions generally result in minimum costs to all parties, even though they sometimes result in over design.

Once the team designs a fix, discuss necessary paperwork with your client. The paperwork should be handled like a shop-drawing revision, with document numbers and other specific information. Fabricators will commonly use a "Field Work" (FW) form to document the work. It is important that the inspection agency have an approved copy of the fix so they can verify the work was done properly.

Uh-oh, the anchor rods don't line up!

One problem commonly encountered is when anchor rods are incorrectly located and don't line up. Here are some steps to consider and proceed with a field fix:

1. Evaluate the need for the incorrectly located rods; perhaps not all of them are required.
2. Cut rods and use epoxy anchors.
3. Cut base plate and use plate washers.
4. Fabricate a new base plate.
5. Relocate the column on the base plate.
6. Modify the column web or flange as required.
7. Bend the rods into position. This could require chipping of concrete.

One of the most common construction errors is the placement of the anchor rods in the wrong location. Several solutions are available for correcting the problem depending upon the degree to which the rods are mis-located. If only one or two rods are mis-located, the mis-located rods can be cut so that they do not interfere with the erection of the column. Due to the OSHA requirement of four anchor rods, this might not be a viable solution; but the erector will be aware of the situation and could take special precautions in erecting the column.

If the cut anchor rods are required, another solution is possible. If existing anchor rods are in the way of the drilling, the holes will have to be relocated. If the anchor rods are used for shear transfer, the plate washers might have to be welded to the base plate. If the column is to be relocated on the base plate, the base plate can be turned over to avoid clean up.

How to minimize anchor rod snafus:

1. Use a qualified field engineer to layout the anchor rods.
2. Use AISC-recommended hole sizes in the base plates.
3. Use symmetric patterns for the anchor rods.
4. Use wood or steel templates firmly fastened to the footing or pier forms.

There is no way to guarantee that anchor rods will be placed correctly. But the first method of prevention is the use of a registered surveyor or qualified construction engineer to lay out the anchor rods. This means a more accurate placement of the anchor rods will occur as compared to when a general contractor's carpenter foreman lays out the rods. Equally important is that the anchor rods be held firmly in place by an accurate setting template secured to the forms. For most jobs this is a plywood template made by carpenters. For large rods in tension-type footings, it might be advisable to use a steel setting plate to ensure accurate placement.

Two ways to prevent interference with the column base plates are: 1) Survey the anchor-rod placement before column fabrication so that the holes in the base plates can be adjusted for location errors, and 2) Use AISC-recommended hole sizes in the base plates. Refer to the AISC 3rd edition *LRFD Manual of Steel Construction* for suggested anchor-rod hole sizes.

Suggested solutions to solving the misplacement of anchor rods are:

1. Extend a short anchor rod by welding on a threaded extension: Shown in Figures 1 and 2 are weld details that could be used to properly extend anchor rods. Before welding, check if the anchor-rod material is weldable.
2. Use a coupling nut to extend the rod: The AISC *Manual* shows coupling nuts that are capable of developing the full strength of the rod.
3. Cut the rod(s) and use epoxy anchors: It is the opinion of the authors that epoxy anchors are better than expansion anchors
4. Weld the base plate to the rods (not high for strength rods): A plate washer can be slipped over the anchor rod so that the anchor rod can be welded to the plate washer.
5. Perform analysis for nut using the threads engaged: This can be done based on a linear interpolation of full threads engaged, versus the number of threads in the nut.

It should be noted that the OSHA requirement of guying the column or holding the column with the crane must be followed until four anchor rods are secured.

Preventing anchor rods from being too short:

1. Provide a design with ample length, and ample thread length.
2. Do not use high-strength-steel anchor rods, use larger-diameter rods.

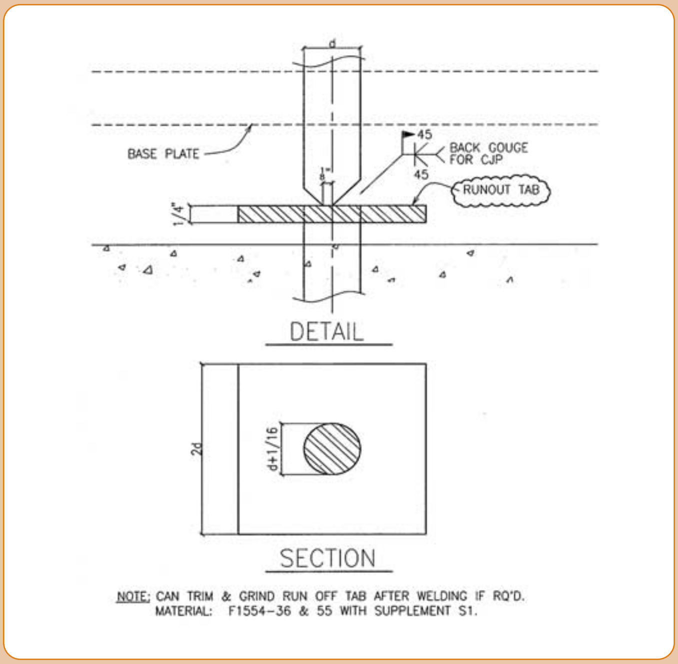

Figure 1.
In order to properly groove-weld a threaded stub to extend an anchor rod, it is necessary to first prepare the joint by beveling the stub to a chisel point. Next, a run-off tab must be provided. This can be done by taking a 1/4"-thick plate with a hole 1/16" larger than the rod. Then tack-weld the tab flush with the top of the embedded rod. The weld then can be placed in the groove and extended out onto the plate. If a CJP weld is required the weld should be gouged to sound metal before welding the second side. This can be done with a grinder. If necessary for clearances, the run-off tab and excess weld can be cut off after the weld is complete.

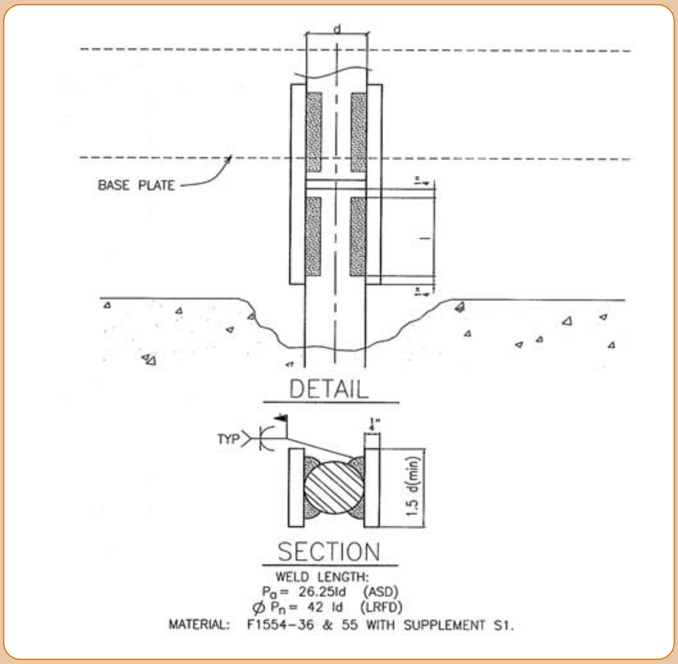

Figure 2.
It is possible to splice an anchor rod using two pieces of flat bar stock.
- The strength of four flare bevel groove welds are as shown.
- The minimum weld length should be at least 1".
- The required plate area should be checked for tension capacity.

It is important that the welder be certified to weld in the vertical position. OSHA requires all anchor-rod modifications to be approved by the SEOR. The authors suggest that you have a series of standard fixes similar to the details shown in Figures 1 and 2 in your files, so when the inevitable does occur, you have a quick, well-reasoned response to a field fix.

To camber or not to camber...

The following members should not be cambered:
- Spandrel beams (especially those supporting fascia materials).
- Beams with cantilevers.
- Beams braces with knee braces.
- Members of non-uniform cross section.
- Beams with significant non-symmetrical loading.
- Beams subjected to torsional loads.
- Beams less than 25′ in length.
- Beams with web 1/4" or less.
- Beams which require less than 1″ of camber.
- Beams in braced frames.
- Don't over-camber beams that receive shear studs for composite action. Depending on the method of concrete placement, over-cambering can result in the heads of the studs protruding from the top of the concrete slab.
- Be careful of camber differences between beams and joists.
- Be careful of cambered beams or joists adjacent to non-cambered end walls.

The following items from the AISC *Code of Standard Practice*, Section 6.4, should be remembered:
- The camber tolerance is minus zero/plus ½″ with an additional 1/8″ per each additional 10′ of length (or fraction thereof), allowed for lengths in excess of 50′.
- These tolerances are workmanship guidelines and should not be considered absolute.
- The AISC *Code* indicates that camber is measured in the un-stressed position in the shop.

Preventing Paint Problems

1. **Mill scale lifting:** Specify proper surface preparation. The service conditions determine the surface preparation. An SSPC-SP2 properly done is adequate for non-corrosive interior applications. Exterior applications or corrosive exposures should be blast-cleaned to an SP 6 or SP 10 as required.
2. **Paint lifting:** Solvent-clean to remove forming lubricants. HSS usually have a lubrication residue from forming. A thorough SP 1 solvent-clean is required to ensure the primer adheres properly.
3. **Runs and sags:** Control wet film; perhaps use high solids. HSS are formed from hot-rolled strip that do not have mill scale. The smooth surface allows paint to flow easily, so coating thickness must be controlled closely.
4. **Mud cracks:** Reduce wet film in overlap areas. Inorganic zinc primers tend to mud crack when over-built. This typically happens in areas where overlap occurs. This can be repaired by sanding to the specified thickness.
5. **Pin holes:** A member's prime coat should be cured before it is top-coated. Inorganic zinc primers require moisture and time to properly cure. If they are top-coated too soon, pin holes develop.
6. **Chipping:** Again, a member's prime coat should be cured completely before before it is top-coated. Inorganic zinc, if top-coated too soon, will not develop adequate coating strength.

The hard epoxy intermediate coat will cause the primer to shear when hit. This is evident by the zinc on the chip and on the piece. Organic/epoxy zinc-rich primers are recommended for multi-shop coat systems because they are more user-friendly and give similar protection.

Keeping Connections Clean

Shear Connections:

- Show reactions on framing plans.
- Use AISC-recommended details for:
  - Double Angle–bolted/bolted or bolted/welded connections for beam-to-column.
  - Single Angle–for beam-to-beam connections.
  - Single Plate–for beam-to-beam and skewed connections.
  - End Plate–heavy skewed connections.
- Show special connections on the drawings.

Moment Connections:

- Provide the actual moment envelope.
- Design considerations:
  - End plates can be limited by bolts or column-flange bending capacity.
  - CJP welds are a "no brainer" but generally are more expensive.
  - Top and bottom bolted plates are an option if less than M_p is required.
  - Size columns to avoid stiffeners and doubler plates.

Gravity loads tend to dominate on most moment connections, so the connection seldom needs to be designed for full-load reversal. When wind moments govern, the sections often are selected for drift control, and the connections can be designed using bolted end plates with no column stiffening.

Bracing Connections:

- Show all forces for a complete load path, and provide equilibrium conditions at joint.
- Transfer forces should include all drag strut forces and diaphragm connection details.
- Consider modifying work points for extreme connection geometry.
- Allow oversize holes and field welding where required for constructability.

It is important to provide complete load paths for all lateral loads and column-stability requirements. This includes diaphragm shear checks and chord forces, drag strut, and pass-through forces required to get the loads to the lateral-force resisting system. If at all possible, forces at a joint should be given in an equilibrium condition so the connection-force transfer can be designed. ★

James M. Fisher is vice president, Computerized Structural Design, S.C., Milwaukee. Lawrence A. Kloiber is vice president of engineering at LeJeune Steel Co., Minneapolis. He is AISC's 2004 T.R.Higgins Award winner.