

# Structural Steel Detailing Practices—Good and Bad

HUGH DOBBIE

*This paper was presented at the 2003 North American Steel Construction Conference.*

The topics presented in this paper are listed below. They are all amply described in the AISC manual, *Detailing for Steel Construction* (DSC) (AISC, 2002).

- Chapter 4—Basic Detailing Conventions
- Chapter 5—Project Set-up and Control
- Chapter 7—Shop Drawings and Bills of Material
- Chapter 8—Detailing Quality Control and Assurance
- Appendix B—Electronic Design and Detailing

## BASIC DETAILING CONVENTIONS

The objective of this chapter is to define detailing conventions that are in universal use. Over the years, innovation, trial and error, common logic, and a desire to improve the product (shop and erection drawings) have combined to evolve the standard practices and conventions we use today.

### General Drawing Presentation and Drafting Practices

Figure 1a (before clean-up) shows a typical example of how some computer systems may detail a simple beam. The picture is somewhat cluttered, with dimension lines crossing each other.

Figure 1b (after clean-up) shows how the beam would look after the details have been clarified to make a better presentation.

- a. In Figure 1a (before), the running dimensions for the web holes are shown on two separate lines and are mixed with the center-to-center of the web hole connections.

Figure 1b (after), shows the running dimensions to the web holes in one line, with the center-to-center dimensions for the holes offset, making a much clearer picture. The first running dimension is also shown from its point of origin.

- b. In Figure 1a (before), the dimensions at the end of the beam above the top are stacked one above the other, with many lines crossing each other. By moving some of the dimensions to the underside of the bottom flange as in Figure 1b (after), the picture is substantially clarified.
- c. Similarly, the vertical holes in the clip angle are shown on the same side in Figure 1a (before). By moving the dimensions for the web holes to the right, and having the dimensions for the outstanding leg on the left, as in Figure 1b (after), the picture is easier to read.

There are other minor adjustments that make Figure 1b (after) a cleaner presentation and easier to interpret.

- **Lettering** should be neat and legible. This is no longer a problem because the computer now enables us to produce a standard text on drawings.
- **Notes** should not run into the sketch or its dimensioning and general notes should be placed near the title block. The detailer should keep in mind that the shop worker must read the drawings under conditions of less light and cleanliness than that available to the detailer.
- **Good line contrast** is important. Thinner lines should be used for dimension lines and bolder lines for object lines. Sometimes on computer-generated drawings the contrast in line types is not sufficient for a clear presentation. The detailer must be careful to set the line weights for the details.
- **Dimension lines** should be far enough from the sketch to allow sufficient room for dimensions. Generally the first dimension should be approximately  $\frac{5}{8}$  in. from the sketch and each succeeding line about  $\frac{3}{8}$  in. apart.
- **Sections** should be taken looking to the left and looking towards the bottom of the drawing. Avoid looking up and to the right.

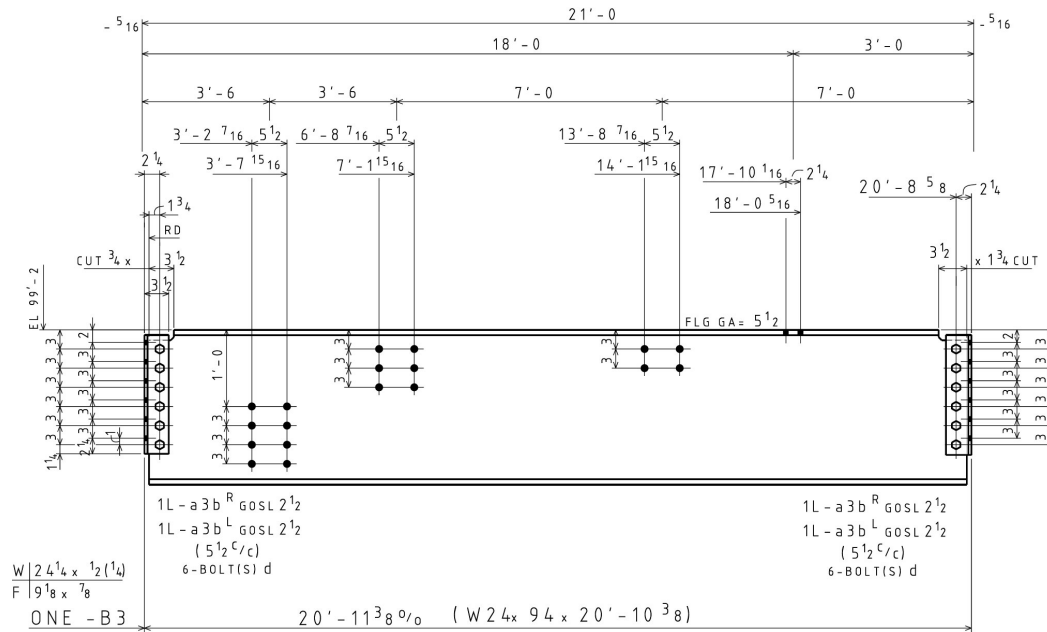
### Bolting and Welding

Never use the word “weld” on a drawing as a symbol. Always apply the appropriate ANSI/AWS symbol to a welded joint.

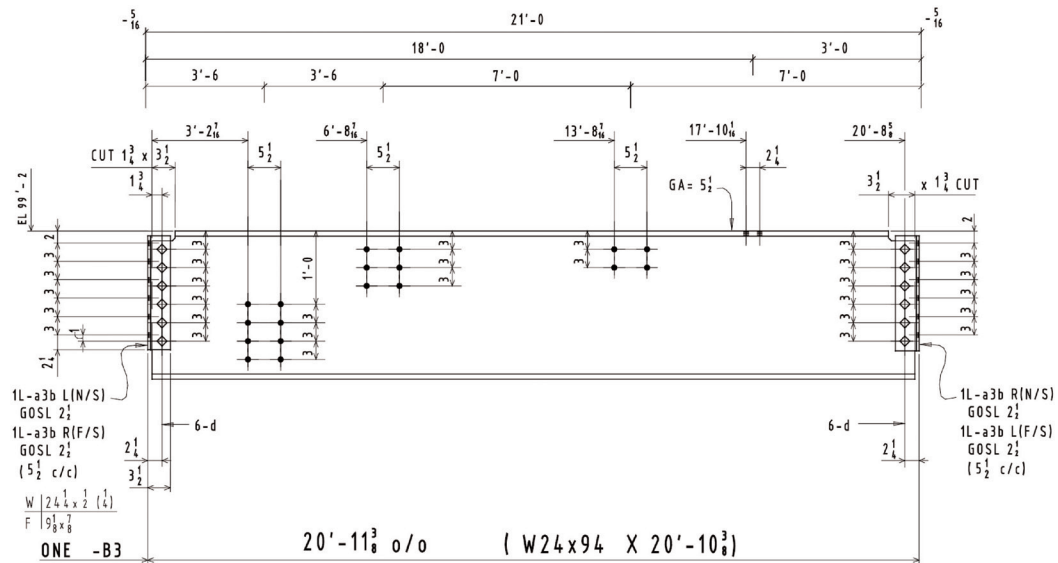
---

Hugh Dobbie is president, Dowco Consultants Ltd., Burnaby, British Columbia, Canada.

---



(a) Before



(b) After

Fig. 1. Typical example of computer detailing before and after clean-up.

- Never use more welding than is necessary, as this adds to the cost of fabrication and/or erection and may cause the member to warp. Too much weld *does not* make a better joint.
- Where fillet welds on opposite sides of the same plane come to a corner, interrupt them as shown in Figure 2.
- Avoid producing details which show fillet welds wrapped or returned around the ends of material as shown in Figure 3.

### Shop and Field Considerations

The detailer should be sure that ample clearances are allowed to cover variations in cutting, shearing and coping. Approximately  $\frac{1}{2}$  in. is advisable for shop clearance and  $\frac{3}{4}$  in. to 1 in. is recommended for field clearances, depending on conditions of framing.

When a project calls for studs to be welded to the top flanges of beams or girders, the studs must be applied in the field. The top flanges of such beams should not be painted.

Examine all field conditions to be certain that bolts can be inserted and tightened, especially in skewed configurations.

The structural detailer will have frequent reference to the concept of detail and/or main shipping pieces that have been, or could be, drawn and billed as “right hand” or “left hand” (mirror image.) Today most fabricators are restricting the use of this shortcut concept because, while the work of the detail drawing may be reduced somewhat, the opportunity for shop errors increases considerably. CAD systems, while readily able to create a mirror image, are not able to handle the complexities of combination detailing. Additionally, a CAD system can quickly create a shop drawing of the piece which would have been combined as a left-hand piece.

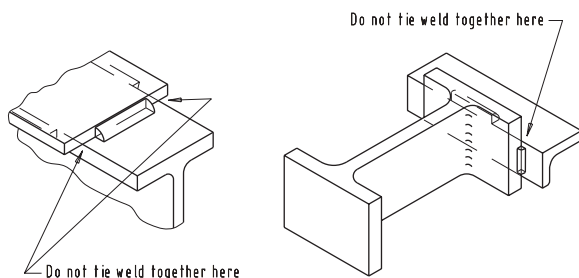


Fig. 2. Weld terminations.

### Detailing Economy

Shop and drawing room time can be saved by the use of standardized connection material. Most fabricators have developed standard beam connections, based on the framed and seated connections shown in the AISC *Load and Resistance Factor Design Manual of Steel Construction* (AISC, 2001), hereafter referred to as the AISC Manual, which can be used on columns with a minimum of dimensioning.

A similar practice with even greater potential savings is the employment of job standards. These cover connection material of all descriptions that repeat throughout a particular structure. Complete details and material billing with assigned standard assembly marks are developed and drawn on sheets separate from the shop drawings. By this means, fitting (from simple splice plates to complex moment connections) may be copied onto shop drawings using only those dimensions required to locate the connections and fabricate the main material. Another system “sub-assembly detailing” presupposes a number of members (columns, girders, trusses, etc.) which have identical main material, but which differ in some degree as to detail fittings or other minor fabrication. Sub-assembly details are prepared showing only the fabrication which repeats exactly on all the members. The advantage of this procedure is that the shop can complete the bulk of the work on a run of identical sub-assemblies more efficiently than would be the case if each piece were worked individually perhaps from separate drawings. Partially completed work may then be stockpiled until needed for final fabrication and shipment. Of course, this system should be used only after consultation with the shop, and with the shop’s full concurrence.

### Bolts

Most of the information available on bolts is the product of the Research Council on Structural Connections (RCSC,

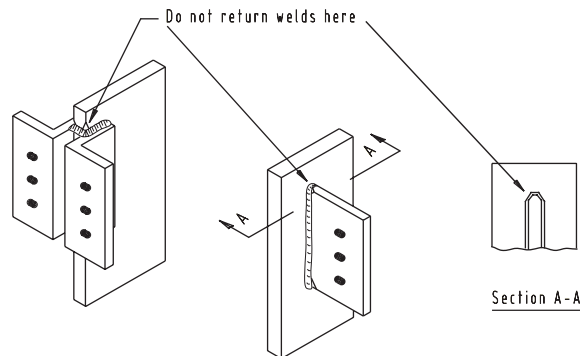


Fig. 3. Weld returns to avoid.

2000). The detailer should be familiar with the current document and use it in conjunction with the new DSC manual.

### Welding

There is a comprehensive component covering welding in the new text. Specifications for structural welding have been standardized by the American Welding Society in *Structural Welding Code—Steel*, ANSI/AWS D1.1 (AWS, 2002), hereafter referred to as the AWS Code. Specification requirements for welded connections in building construction are provided in the *AISC Load and Resistance Factor Design Specification for Structural Steel Buildings*, hereafter referred to as the AISC Specification (AISC, 1999). The fabricator should have a written welding procedure specification that should be available to the Structural Engineer of Record (SER) and the inspector. The detailer should also be informed of any special procedures that should be noted on the detail drawings. The AISC Specification dictates

bolts and welds should not be combined in the same shipping piece.

### Welding Positions

The position of a joint when the welding is performed has a definite structural and economic significance. It affects the ease of making the weld, the size of the electrode, the current required and the thickness of each weld layer deposited in multi-pass welds. The following basic weld positions are shown in Figure 4:

1. *Flat*: The face of the weld is approximately horizontal and welding is performed from above the joint.
2. *Horizontal*: The axis of the weld is horizontal. For groove welds, the face of the weld is approximately vertical; for fillet welds the face is usually at 45 degrees to the horizontal and vertical surfaces.
3. *Vertical*: The axis of the weld is approximately vertical.
4. *Overhead*: Welding is performed from the underside of the joint.

The AWS Code prescribes limits of angular deviation from true horizontal and vertical planes for each of these weld positions. The flat position is preferred in all types of welding because weld metal can be deposited faster and easier. For example, a  $\frac{5}{16}$  in. manual fillet weld may require 50 percent more time to deposit in the horizontal position than in the flat position. Note that submerged arc welds generally are restricted to the flat position. Vertical and overhead welds may take three times as long as the same weld made in the flat position. In the shop, the work usually is positioned to permit flat or horizontal welding. This is done either by rotating the member (as when joining flat plates with welds on both sides) or by use of welding positioners which tilt the work to a suitable position for flat or horizontal welding. As field welding seldom permits positioning, vertical and overhead welds often cannot be avoided. However, careful planning in the drawing room can minimize the need for such welds by arranging field-welded joints for flat or horizontal welds, wherever possible.

Figure 5a illustrates the placement of a single-vee groove weld with the face upward and a backing bar underneath to eliminate overhead welding. Figure 5b shows a double-vee groove weld with an unsymmetrical profile, with the smaller groove placed on the bottom to reduce the amount of work in the overhead position.

### Economy in Selection of Welds

In addition to detailing joints for the best welding position, the structural detailer can achieve economy by selecting welds which require a minimum amount of metal and can be deposited in the least amount of time. As shown in

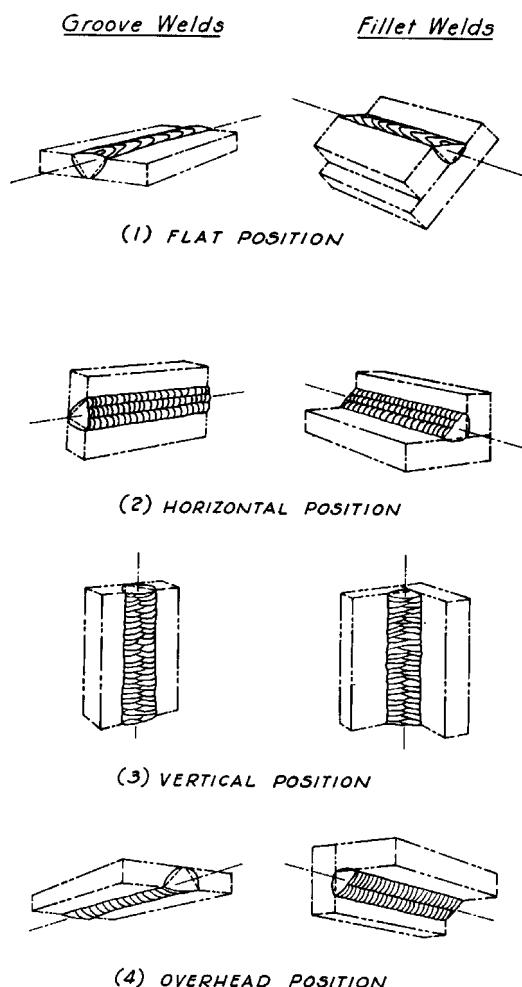


Fig.4. Basic weld positions.

Chapter 3 of DSC, the strength of a fillet weld is in direct proportion to its size. However, the volume of deposited metal and, hence the cost of the weld, increases as the square of the weld size. A  $\frac{5}{8}$  in. fillet weld contains four times the volume required for a  $\frac{5}{16}$  in. weld, yet it is only twice as strong. For this reason, specifying a smaller, longer weld (rather than a more costly larger, shorter weld) frequently is preferable.

### Welding Symbols

Shop and erection drawings for welded construction must provide specific instructions for the type, size and lengths of welds and their locations on the assembled piece. The welding symbols generally used are described in the DSC text and are obtained from the AWS booklet *Symbols for Welding, Brazing and Nondestructive Examination* (AWS, 1998). An over-abundance of welding symbols on a drawing can be confusing for the fabricator. Symbols should only be shown once for each joint (see Figure 6).

Symbols for field welding are identical to those for shop welding, except that the welding symbol is identified by a small, blackened, extended flag placed at the juncture of the arrow and reference line. The point of the flag must point towards the basic weld symbol as shown in Figure 7.

### Painting

Improper painting notes can be costly for the fabricator. On each shop drawing the detailer notes whether painting of pieces on that sheet is required. Often the pre-printed sheet will have a block of information near the title block for the detailer to complete. The detailer completes the block by indicating whether or not painting is required. If connections require using ASTM A325 or A490 bolts, or similar fasteners, in non-coated slip-critical joints, paint on faying surfaces and surfaces adjacent to the bolt head and nut shall be excluded from areas closer than one bolt diameter, but not less than 1 in. from the edge of any hole and in all areas of the bolt pattern. It is a good practice not to combine painted and unpainted items on the same drawing.

Paint is also omitted where field welding occurs. Primarily these areas include field welded connections and the tops of members requiring the field application of shear studs.

If steel is to receive sprayed-on fireproofing, typically the steel must not be painted. Otherwise the sprayed-on fireproofing may not meet the adhesion requirements of the Underwriters Laboratories.

The detailer must pay a strict adherence to these areas requiring “no paint,” in order to mitigate potential field charges for removing paint from the steel.

### Galvanizing

Galvanizing is the process of applying a protective coat of zinc to steel products to prevent corrosion. The zinc coating is applied usually by the hot-dip process. This involves dipping the material in a series of cleansing and rinsing tanks to thoroughly clean the steel before dipping it into a tank of molten zinc, which has a temperature of approximately 840 °F.

The following checklist is presented to identify the most common considerations for the detailer to use when preparing shop drawings for galvanized material:

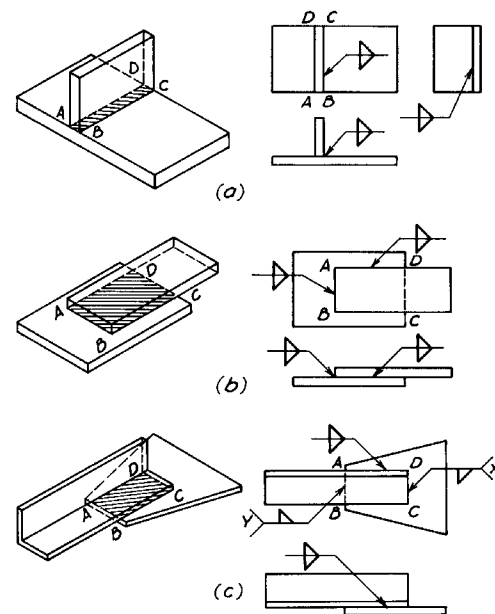


Fig. 6. Fillet welds.

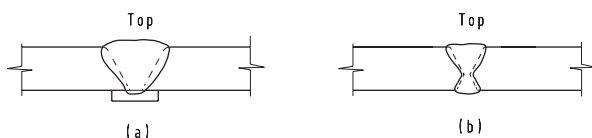


Fig. 5. Vee-groove welds.

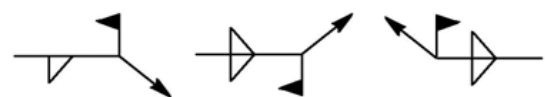


Fig. 7. Field welds.

1. Identification of galvanized material on the shop drawings.
2. Maximum size which can be galvanized.
3. Bolted connections.
4. Welded connections.
5. Seal welding requirements.
6. Use of galvanized bolts.
7. Drain and vent holes. See Figures 8 and 9.
8. Field welding precautions.
9. Pieces to be galvanized should be detailed on drawings separate from other fabrication.

## UNERECTABLE CONDITIONS AND OSHA

### Safety Requirements

The detailer must ascertain that the pieces being detailed can be erected. This involves familiarity with rolling mill and shop tolerances and the clearances required for erection. Also involved is accuracy in matching connections such as, for instance, the quantity and location of holes in a knife connection on a column flange matching the holes at the end of a beam which will connect to the angles. Another

condition which can cause erection problems occurs when bent curb plates are shop welded to the top flange of a spandrel beam which connects to the web of a column. As the bent plate is notched to fit around the flange of the column, the piece is awkward to erect.

Further, if the plate is expected to support curtainwall framing with tight tolerances, the customary combination of rolling mill, fabrication and erection tolerances may be unacceptable. In this situation, the solution likely would be to field weld the curb plate to the beam.

In order to erect beams onto seats in column webs, the detailer must remember that the beams are to be lowered between the flanges of the column, and that other fittings on the column must provide the required clearance to permit erection.

OSHA (Occupational Safety and Health Administration) issues workplace rules for the benefit of workers. These rules establish the quality and safety of the work area environment. Fabricators maintain a volume of OSHA regulations pertinent to their operations. Subpart R—*Steel Erection* found in the OSHA regulations contains requirements with which the detailer should be familiar.

## PROJECT SET-UP AND CONTROL

The objective here is to define the detailing conventions that are project specific and should be established when starting a new project.

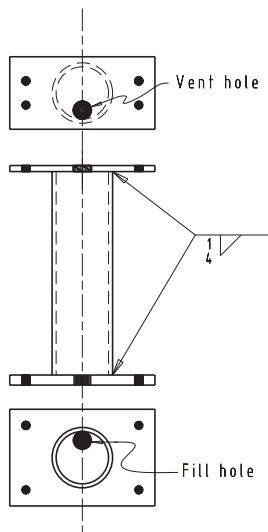


Fig. 8. Vent holes.

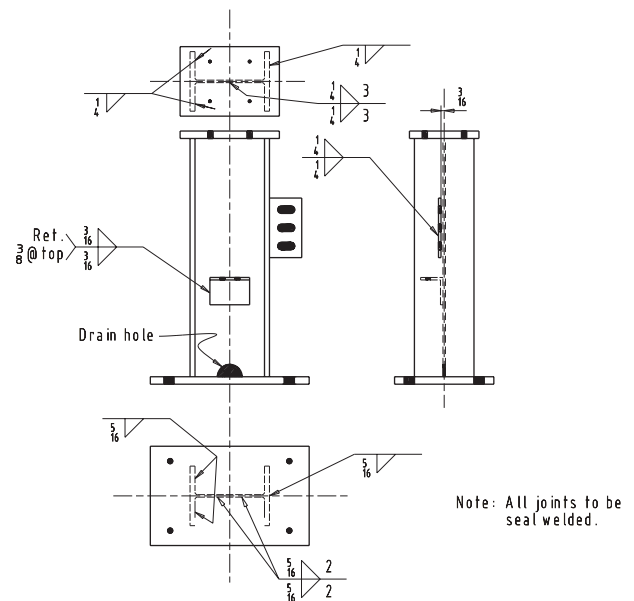


Fig. 9. Drain holes.



## **Pre-Construction Conference**

### *Detailing Kick-Off Meeting Topics*

At the beginning of a project it is advantageous to hold a meeting between various members of the construction team. The purpose of this meeting is to establish guidelines and rules for the development of the project throughout detailing, fabrication, and erection. The detailer must take direction from the customer (which is typically a fabricator). However, the detailer will need to take into consideration the work of other trades and incorporate certain details into the drawings with the permission of the detailer's customer. Below is a generic outline of the topics that may be discussed at such a meeting.

#### **I. Contract Document Review and General Project Overview**

- A. Establish the most current set of contract documents and confirm that all trades are working with this set.
- B. Clarify scope if required.
- C. Identify areas of concern such as critical tolerances, construction phasing, coordination with other trades, etc.
- D. Provide preliminary layouts showing the sequencing system to be used. This should include the lines of demarcation between sequences and the piece-marking system. The sequencing needs to be reviewed by the General Contractor for access and coordination with other trades.
- E. Confirm which codes are applicable (ASD, LRFD, UBC, BOCA, City codes, etc.).
- F. Discuss any special concerns such as material grades, anchor rod grades, weld rod specifications, paint, etc.
- G. Determine which areas of the structure are to be re-designed, if applicable.
- H. Locate "Contractor Designed" items such as hand-rails, metal stairs, elevator machine room framing, etc.
- I. Review OSHA requirements and incorporate details required for OSHA conformance.

- J. In projects involving remodeling work, identify the schedule for field measuring and exploratory demolition.

#### **II. Detailing Program and Coordination Issues**

- A. Discuss detailing methodology to be used.
  - 1. The detailer should be provided with the fabricator's and erector's standard details.
  - 2. Bolt diameters and grades, and hole size should be provided in the contract documents. However, the detailer and fabricator should review this matter for a number of reasons.
    - a. Select bolt diameters and grades to suit the loads when connections are to be designed by the fabricator.
    - b. Maintain a  $\frac{1}{4}$  in. difference in diameters to avoid installing an undersized bolt in a joint.
    - c. Try to maintain one bolt grade if feasible. In any event, do not use two different grades of bolts with the same diameter.
  - 3. Tension-Control versus regular hex-head bolts. The entering clearances for tension-control bolts and regular bolts are different and must be considered by the detailer.
  - 4. Confirm which joints are to be designed by the fabricator and which methods of design are acceptable (in other words, elastic method or uniform force method).
  - 5. Simple framed connections may be presented in table format.
  - 6. Oversized and slotted holes may be used with the permission of the Engineer. Although using such holes provides adjustability on the structure, having too much adjustability can cause difficulties for the erector.
- B. Propose alternate details where applicable.
  - 1. Framing angles welded to a beam that connects to column webs on both ends makes it very difficult to erect the beam.

2. Some shops prefer to bolt detail pieces to main members whereas other shops prefer to weld. The engineer must approve switching from one method of attachment to the other.

**C. Discuss any information that may be missing or ambiguous in the contract documents.**

“Drawing Checklist” produced by SEAOC Steel Liaison Committee contains a detailed list of items.

1. Member loads, dimensions and elevations.
2. The location and extent of section cuts and details.
3. Areas that are to be painted and the finish that is required.
4. Areas that are to be fireproofed in the field and are to be left, therefore, unpainted.

**D. Review the location of member splices for constructability.**

Splices in trusses must be located such that the shop and site cranes are able to manage the weights of the pieces. Column splices need to be located such that bolt access is possible from the floor level and so that a safety cable may be installed in the column being spliced (Ref. OSHA).

**E. Determine if erection aids are required** such as lifting lugs and temporary connections. Establish the size and location of the lifting holes.

**F. Establish what sorts of details are required to accommodate other trades** such as beam penetrations and supporting frames for roof equipment. If this information is not immediately available then:

1. Provide the Owner with dates for the release of the required information such that detailing is not impacted.
2. Ask if it is possible to assume “safe” locations, dimensions, and details. Proceeding on this basis would be carried out at the risk of the Owner in the event that the final

details are different than the assumed details.

**G. Discuss the Advance Bill of Material (ABM) with the fabricator.**

1. Develop a schedule for submitting the ABM's for material procurement.
2. Confirm what information needs to be provided on the ABM other than the material size and length (in other words, mill certificate requirement, charpy testing, domestic material requirements, etc.)

### III. Communication

**A. Set up a Request for Information (RFI) system.** Each RFI should be restricted to one question. It is helpful to include a numbering scheme that identifies the trade and company, and a distribution list. Identifying the company can usually be accomplished by including the initials of the company name in the RFI number.

**B. Request that direct contact be permitted** between the fabricator/detailer and the Architect/ Engineer. Official paperwork should follow any such communications for record purposes.

**C. Request that an advance courtesy copy of the approval drawings** be sent to the engineer/architect to help speed up the approval process.

**D. Establish a regular schedule for meetings** and/or conference calls and determine who shall be present.

### IV. Detailing Submittal Schedule

**A. Determine how many prints** and reproducible drawings are required for approval and for field use.

**B. Connection designs** are to be submitted well in advance of the detail drawings so that the detailer can produce detail drawings with approved connections.

**C. Provide a detailing submittal schedule.**

1. Submittals should contain complete sequences.



2. The AISC *Code of Standard Practice* (AISC, 2000) stipulates that the fabricator is to allow 14 calendar days for the return of drawing submittals.

**D.** If **schedule-critical areas** exist on the project, such areas should be pointed out to the engineer/architect and request an accelerated turn around on the applicable drawings. It is impractical to expect a quick return of all submittals, so good judgment must be used when requesting such.

## V. Changes to the Contract

### A. Determine how changes are to be dealt with.

1. The Owner will decide whether changes are to be incorporated immediately or if cost and schedule impacts are to be provided to the Owner for review before proceeding.
2. In the event that the Owner wants to review cost and schedule impacts before deciding whether to proceed with a change or not, supply dates for when a decision must be made in order that the work is not effected further.
3. Some contracts require unit prices for various changes. Determine if the changes in hand fit into a unit price category or not.
4. In any event, the detailer shall take direction from the customer regarding the incorporation of changes.

Depending on the number of changes, it may be necessary for the detailer to maintain and distribute a "hold list." This list will include the piece mark, quantity of pieces, current status of the piece (not drawn, at approval, in the shop), the date the pieces were put on hold, why the pieces were put on hold, and a release date.

## VI. Quality Control/Nonconformance Issues

**A. Review the shop and field inspection requirements.** Any alternate details should be selected in light of the inspection requirements so as not to add extra inspection work.

**B. Destructive testing of bolts** is common, but the number of bolts tested is generally small. In the event that the destructive testing becomes exhaustive, the number of bolts to be tested must be incorporated into the bolt lists provided by the detailer. This is normally handled by adding a certain percentage to the bolt quantity.

**C. Charpy V-notch testing** should be noted on the ABM and the shop drawing.

**D. Modifications made to pieces** either in the shop or in the field will require a drawing.

1. Shop rework can be handled by revising a shop drawing and issuing it to the shop.
2. Field modifications require a fieldwork drawing, which is normally labeled "FW-XXX." This drawing should provide complete and clear instructions to the erector on the modifications to be made.
3. Both types of drawings should provide a reference to the source of the rework (contract change, nonconformance number, customer request, etc.). This can be provided by either a brief description or a code. The detailer should also keep a log of these drawings with summary information for record and management purposes.
4. Update the hold list to incorporate non-conformances.

**E. A "Punch List"** will be developed and maintained by the inspector and will be distributed to the affected parties. Items contained in the punch list may address misfits, untorqued bolts, mislocated holes, nonconforming welds, and so on. Accordingly, certain items will require action on the part of the detailer, while other items will not.

Upon the conclusion of the kick-off meeting, a set of meeting minutes shall be drawn up by the General Contractor and distributed to the parties that attended the meeting.

## SHOP DRAWINGS AND BILLS OF MATERIAL

Steel is a demanding material with which to work. Its attractive qualities (durability, strength and the ability to be fabricated with great precision) also render it an unrealistic and unforgiving material to be reworked on site.

The shop drawing provides a precise picture of each steel element and how it is to be made. Through the detailing process, every component of the steel sub-contractor's scope of work is scrutinized, dimensionally defined, and given an identifying mark. Every bolt is located and defined and each shop operation is identified.

The steel detailing industry provides professional services, combining engineering technologists and drafting skills on a contract basis. Although detailers are not required to be engineers, they must know and understand engineering terms and principles. By the same token, detailers are not normally welders, iron workers or erectors, but they must have a solid understanding of these trade skills in order to communicate effectively.

Chapter 7 in the new *Detailing for Steel Construction* manual covers many of the techniques used by detailers to present the information to the fabricator in a clear and concise manner.

### Detailing Errors

Utmost care must be exercised by the detailer in assuring that every bit of information given on a drawing (shop or erection) is accurate. Detailing errors can spell the difference between the fabricators making a profit or not. Following are some of the more common errors found on shop and erection drawings.

#### Dimensional

The total of a series of incremental dimensions (for instance, giving spacing between groups of holes in a beam web) does not agree with the extension dimensions to one or more groups. Also the bottom hole in a line of holes in the web of a beam (the holes being dimensioned from the top of the beam) is too close to the bottom fillet to permit acceptable attachment of a fitting.

#### Bills of Material

The billed weight and/or size of a rolled shape disagrees with the description shown on the drawing. Also, the width and/or length billed for a plate does not match the detail drawing. Another error by the detailer is when a piece is billed in the shop bill longer than the size of the material ordered for it. The detailer has the responsibility to ascertain that the material ordered is adequate to make the piece. If the material is undersized, the detailer must prepare a material change order to provide the correct size or length. Another error occurs when the quantities or pieces (assembly or shipping) are wrong.

#### Missing Pieces

This is caused when the detailer fails to produce a shop drawing for a piece required on a job.

### Clearance for Welding

In manual welding, in order to deposit a satisfactory weld, the operator must have sufficient room to manipulate the electrode and must be able to see the root of the weld with the protective welder's hood in position.

Other things being equal, the preferred position of the electrode when welding in the horizontal position would be in a plane forming an angle of 30 degrees with the vertical side of the fillet being laid down. However, in order to avoid contact with some projecting part of the work, this angle, angle X in Figure 10a and 10b, may be varied slightly. A simple rule used by many fabricators to ensure adequate clearance for the passage of the electrode in horizontal fillet welding, is that the root of the weld shall be visible to the operator, and that the clear distance from the weld root to the projecting element, which might otherwise obstruct passage of the electrode, shall be at least one-half the height of the projection—distance  $y/2$  in Figure 10b.

A special case of minimum clearance for welding with a straight electrode is illustrated in Figure 11 (which shows a beam as it would lie on the skids with its web in a horizontal position). In this case, the governing obstruction is the inside of the flange.

One technique used by fabricators is to cut the end (noted optional cut in Figure 11) of the connection angle to a bevel and thereby gain additional clearance. The width of the over-hanging flange is a major factor in determining how

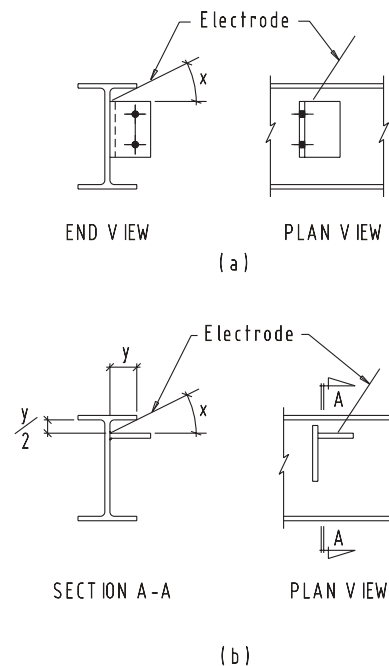


Fig. 10. Preferred electrode position.

much room is required for welding. Welding connections of this type in the web of a column are difficult, particularly because of the “boxing” effect created by the projecting flanges of the column.

Another clearance which is critical to the deposition of fillet welds is the “shelf” on which it is to be placed. Figure 12 shows the minimum recommended shelf for normal size fillet welds made with the shielded metal arc welding (SMAW) process. Submerged arc welding (SAW) would require a wider shelf to contain the flux, although sometimes this is provided by clamping auxiliary material to the member.

The detailer must not only consider clearances required to manipulate the welding electrode, but also must provide adequate space to permit depositing the required fillet weld. In Figure 13 welds are shown along the toes of two  $3 \times 3 \times \frac{5}{16}$  connection angles. Section A-A shows that the nominal dimensions of the connected parts provide only  $\frac{1}{8}$  in. of surface width on the column flange for each weld. If the details call for  $\frac{3}{16}$  in. or  $\frac{1}{4}$  in. fillet welds, obviously the welds cannot be made. The detail shown in Figure 13 is not a good detail, even if the column flange is  $6\frac{3}{4}$  in. wide, because any slight deviation in the actual dimensions of the work due to rolling or fabrication tolerances would result in an undersized weld.

#### Clearance for Bolting

The assembly of high-strength bolted connections requires clearance for entering and tightening the bolts with an impact wrench. The clearance requirements for conventional high-strength bolts are shown in the AISC Manual.

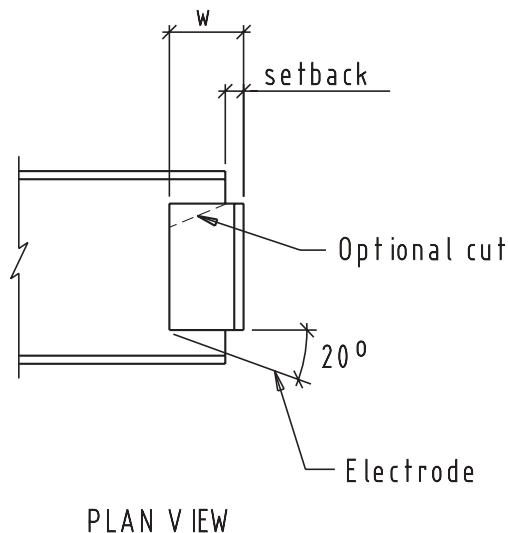


Fig. 11. Minimum clearances for welding with a straight electrode.

Vertical or horizontal section

for $\frac{3}{16}$ fillets	$\frac{1}{2}$	Minimum
" $\frac{1}{4}$ "	$\frac{9}{16}$	"
" $\frac{5}{16}$ "	$\frac{5}{8}$	"
" $\frac{3}{8}$ "	$\frac{11}{16}$	"
" $\frac{7}{16}$ "	$\frac{3}{4}$	"
" $\frac{1}{2}$ "	$\frac{13}{16}$	"

Fig. 12. Minimum recommended shelf for fillet welds made with the SMAW process.

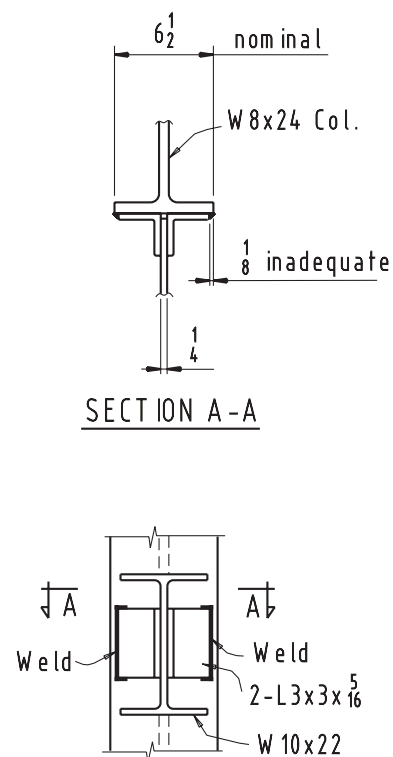


Fig. 13. Fillet weld deposition.

Similarly, for tension-control (TC) bolts, the entering and tightening clearances are given in the AISC Manual. Violation of these clearance requirements could result in unerecable situations, creating costly rework in the field.

#### *Other Detailing Errors*

Some additional detailing errors:

1. The number of bolt holes in a member do not match those in its supporting connection.
2. Bolt holes are the wrong diameter.
3. Gages between lines of holes in flanges of W or similar shapes do not fit the width of the flange. The gage may be too narrow so as to encroach upon the fillet of the shape, or too wide so that the holes are too close to the edge of the flange.
4. Connections are omitted.
5. Copes on beams are missing, unnecessary, too small or too large. Deep or very long copes may require web reinforcing of the beam.
6. Wrong type of steel is used.
7. Wrong weld profile is used.
8. On erection drawings, the north direction is indicated improperly or missing.
9. Combining welding and bolting when such is unnecessary or improper (contrary to the AISC Specification.)
10. Reversing slopes. This is especially a cause for error when the slope is close to 45°.
11. Improper presentation of rights/lefts, as shown/opposite hand, right-hand/left-hand, thus/reverse, all of which are discussed in Chapter 4.
12. Placing incorrect shipping marks on the erection drawings.
13. Omitting bearing stiffeners in beam webs, if required.
14. Omitting required stiffener and/or doubler plates in column webs at moment connections.
15. Painting areas of members on which field welding is to be performed.
16. Painting members to be fire-proofed or embedded in concrete or masonry.

17. Welding symbols are not shown correctly.

18. Painting the tops of members which receive field applied shear studs.

### **DETAILING QUALITY CONTROL AND ASSURANCE**

The first quality control initiative should be an adequate scope list of inclusions, adequate job standards and fabrication and erection preferences for the detailer to incorporate.

Detailing organizations have two main means available to them by which they may be certified to top quality practices and procedures and, thus, are using recognized quality assurance procedures in their offices. Independent firms whose primary business is the production of shop detail drawings, may volunteer for certification through the Quality Procedures Program of the National Institute of Steel Detailing. A fabricator's in-house drawing room becomes certified as part of the certification of the entire plant through the voluntary AISC Quality Certification Program. These programs are devised to confirm to the construction industry that a certified structural steel fabricating plant has the personnel, organization, experience, procedures, knowledge, equipment, capability and commitment to produce fabricated steel of the required quality for a given category of structure. For participating structural steel detailing organizations, these programs function to establish practices and procedures which assure the translation of the intent of contract documents into shop and erection drawings which meet the requirements of the client.

#### **Checking**

The basic function for controlling the quality of the output of the detailing firms is checking. The checker is an individual who, by reason of experience and ability, has advanced successfully from a beginning detailer to a more responsible position.

The checker reviews all documents prepared by the detailer from advance bills to field bolt lists. They are checked for accuracy in quantities, shape nomenclature, description of material, lengths, finish requirements, material specification and any special requirements.

After structural members are detailed on a shop drawing, a copy of the drawing is given to the checker, who reviews and verifies every sketch and dimensions on the drawings. By checking all details, the intent is to ensure that errors have not been made, that standard detailing procedures have been followed and that shop and erection drawings are in full compliance with the contract documents.

## Back Checking

When a checked copy of an advance bill, shop drawing or erection drawing is returned to the detailer who prepared it, the detailer is expected to review all comments and corrections placed on it by the checker. In other words, the detailer checks the checker. If the detailer disagrees with a checker's comment or correction, that individual should discuss the matter with the checker to resolve any differences of opinion on how an item should be presented. The detailer is as much responsible for the accuracy of the drawing as is the checker.

## Approval of Drawing

After detail drawings and erection drawings have been completed, they must be submitted for approval before shop fabrication operations begin. As a rule, this approval is given by the structural engineer of record (SER) or by some other individual whose authority to represent the owner has been established in the contract documents.

Neither the fabricator nor the Detailing Group is responsible for the correctness of dimensions or size of material called for on the design plans or the content of the project specifications. However in preparing drawings, any discrepancies discovered in the design plans or specifications by the Group should be referred to the SER or owner through the communication channels established for the project. Because of the involved contractual relationships which often exist, the referral of discrepancies must be made at the earliest possible moment. Instructions to resolve the discrepancies must be received before proceeding further with the affected portions of the work. Regardless of whether they are found or not, the responsibility for any extra costs that may result from such discrepancies rests with the SER and/or the owner.

## Fit Check

A Detailing Group, at its discretion, or by the fabricator's request, may do a fit check soon after the final drawings for a job or sequence are sent to the shop for fabrication. A fit check is a partial checking of the shop drawings to ensure the proper connection of the members in the field. It should constitute an assurance to the fabricator that all connections will match as detailed, copes and gages are dimensioned accurately, hole sizes and locations are correct. Fit checking is done by an experienced checker. It should be completed prior to the start of fabrication.

Some of today's sophisticated 3D steel detailing programs provide a clash check which does the same as a fit check, but in a much shorter time frame.

## Maintenance of Records

The primary reason for keeping records is to provide a running history of the progress of each piece of material in the job so that its status can be ascertained and/or traced quickly. Good records provide documentation of revisions and other events, aid in the determination or justification of extras and back-charges, and furnish supporting data in the unpleasant event of litigation. Another reason for maintaining records is to provide assurance to a client that a Detailing Group (independent firm or a fabricator's drafting department) is qualified to perform the work assigned to it. The Detailing Group must maintain records to:

1. Record receipt of original and revised design plans and specifications and of other project design documents.
2. Record distribution of these plans and specifications when the Detailing Group is required to send them to other firms performing sublet fabrication for the structural steel fabricator. Such firms may include, but not be limited to, a steel joist supplier, miscellaneous metals fabricator, metal decking supplier, etc.
3. Record each and every advance bill and material change order prepared and its status.
4. Record each and every job standard sheet, layout, shop and erection drawing, field work drawing, field bolt summary, and sketch (for "request for information" or "design clarification") prepared by the Group and its status.
5. Record the receipt and status of each and every "extra" and back-charge involving the detailer.
6. Keep written records of phone conversations with other parties involved with the project as these conversations apply to the conduct of the work.
7. Prepare and submit to the client on a schedule basis a status report indicating the progress of detailing and any problems that may cause delays. The report should include the quantity of shop drawings estimated for the job, detailed, checked, sent for approval, returned from approval and issued to the shop. Also, it should include the estimated date for submitting final shop drawings to the fabricator.

8. Keep faxes, e-mail and other transmissions on file.

Another document retained by the Detailing Group is a log of "extras", which are the costs incurred by the Group in doing work beyond the scope of work originally con-



tracted to perform. Regardless of the cause of the additional work, the detailer must maintain a record which should show the date and source of the change request, its description, its impact on the work of the Group, the resulting cost, the date the extra was issued to the appropriate party and its status (in progress, accepted, rejected, awaiting payment, paid). It should show the time spent to order any additional material and make changes to drawings, and describe in detail the work performed on each drawing involved. The format of these documents will vary from fabricator to fabricator. The importance of carefully and accurately completing these forms immediately upon receiving a change cannot be over emphasized.

Back-charges to the Detailing Group may come from different sources for a variety of reasons. A log of these back-charges must be kept. It should show the date each back-charge is received by the Detailing Group, the source of the back-charge, its cost, a description of the back-charge and the detailer's reply. The forms for recording back-charges can be kept in a file to serve as a log.

Virtually every project is designed and detailed to some extent by phone conversations. Although some of these conversations may be followed up by issuance of revised design plans, revised project specifications or bulletins, a log must be maintained of any and all such conversations dealing with the detailing of the project. The log should at least record the date of the conversation, the parties having the conversation, the subject and the conclusion/decision. As in other record forms, the amount and type of information to be listed depends on the fabricator's preference. One accepted method of maintaining such a log is by using a form (either of the detailer's own making or as issued by the fabricator of the project) on which the above information can be written. The document, then, can be transmitted to other interested parties for confirmation and information. Normally, if a Detailing Group has direct phone access to the SER, it will be required to keep the fabricator informed of all conversations.

To complement the use of direct phone conversations, the communication between the detailer and the SER can be conducted satisfactorily using faxes. By their use the detailer's query and the SER's response are in writing and are available for copying to the fabricator and others as required by contract. Prior to sending a fax, the detailer should alert the SER of a forthcoming fax to help assure an early response.

## **ELECTRONIC DRAWINGS**

### **Direct Benefits of Information Sharing**

The work of detailers is greatly aided by the use of information sharing. Potential benefits for detailers include:

- Time saved to enter the building frame into detailing software.
- Easy adaptation of layered electronic plans into erection drawings by "turning off" unnecessary levels of detail.
- Accurate realization of the design intent into the final product, especially in the case of highly complex or irregular designs.
- Accurate transfer of structural loadings to the fabricator for connection design.

Dominant issues involved in the efficient use of detailing technology include: data format, scale and quality of information.

### **Data**

What is data format? Data format refers to the way that information is delivered in a data set—fonts, numbering, degree of detail, etc. Data formats in electronic drawings are analogous to drafting standards in hand detailing. While each independent producer of drawings could work with an independent standard, the increased ease of information sharing lends itself to one unified format. The term data format is not to be confused with the term file format (such as DXF), which refers to the computer file structure for the reading of information by computer programs, which is outside of the control of the typical designer or detailer.

AISC has evaluated available data format standards and believes that CIS/2 is the most effective standard format for design and construction information exchange. The CIS/2 data format, developed in Europe, is a method of accurately conveying all necessary information for a project with a degree of consistency and accuracy that allows its use by all members of any given project team.

If properly utilized consistent CIS/2 data formatting can save weeks from a project schedule. The benefits of this system will be most easily realized in design-build project delivery systems, where structural steel is often on the critical path of a construction schedule and the underlying goal of the project is mutual benefit derived from working together towards greater overall efficiency, or in a complex project such as a stadium or arena, where a highly specialized design relies on computer methods to complete a very complex structural analysis. The incorporation of CIS/2 data formatting and electronic information sharing into the design process will lead to a more widespread use of structural steel in the construction market and will ultimately create greater profits for steel fabricators and detailers, greater savings to owners, added value for architectural services, and greater efficiency and value for engineers. For more information on CIS/2 data formatting, please see the following website: [www.aisc.org/edi.html](http://www.aisc.org/edi.html).



## Scale

Scale is a critical factor for information obtained electronically from outside parties on any given project team. Architects, construction professionals and engineers occasionally modify scales in drawings in order to make information fit or to make details more clear. The slightest deviation in the scaled versus actual dimension of a drawing demands a thorough review of the drawing, adjustment of the data to accommodate the scale variation and can cause detailing errors which can lead to major problems for steel erection and major cost increases to a project. When using drawings from outside parties who do not assume the responsibility of drawing precision, detailers must beware of the possibility of “exploded dimensions” in drawings—dimensions in which the actual scaled distance measurement of the CAD-drawn line is different from the numeric dimension shown. Design Professionals may employ imprecise dimensions in the development of drawings for conceptual or aesthetic application of design. When the dimensions have been violated, the usefulness of digital information sharing for detailers becomes highly limited. When using information created by an outside party, it is the responsibility of the user of that information to make a judgment on the accuracy of the information. Generally, structural models are much more accurate than drawings as the models themselves rely on members drawn between defined node locations to complete a technical design rather than a conceptual or aesthetic presentation of information.

## Quality Control

With the use of new technologies comes an increased responsibility to ensure that steel detailing does not circumvent the thought process necessary for the development of an accurate and useful product. As is true for any computer software application, the “Garbage in, Garbage out” principle applies—the quality of the end product is only as good as the information entered to develop it. The use of CIS/2 data formatting will help to improve the quality of information by promoting effective checking by the drafter and verification of compliance with design intent by the engineer.

## Where We Are Today

Today only the most advanced building projects make use of the tools available with the development of technology. The most sophisticated proponents of this process can even enter electronic information into a Computer Numeric Control (CNC) automated fabrication system that allows shop drawing information to be accurately uploaded directly to the machinery that fabricates the steel.

The reality of today’s market is a stifling resistance to change in an industry that thrives on tradition. Inefficiencies will persist until the competition makes the technology necessary. People in the industry today must consider how prepared they will be when the technology of tomorrow becomes the reality of the present day.

*The foregoing presentation has been summarized from the new Detailing for Steel Construction manual. This book is a complete rewrite and contains current information on accepted steel detailing practices and should be part of every detailer’s and SER’s library.*

## REFERENCES

- AISC (2002), *Detailing for Steel Construction*, American Institute of Steel Construction, Chicago.
- AISC (2001), *Load and Resistance Factor Design Manual of Steel Construction*, American Institute of Steel Construction, Chicago.
- AISC (1999), *Load and Resistance Factor Design Specification for Structural Steel Buildings*, American Institute of Steel Construction, Chicago, December 27.
- AISC (2000), *Code of Standard Practice for Steel Buildings and Bridges*, American Institute of Steel Construction, Chicago, March 27.
- AWS (2002), *Structural Welding Code—Steel*, ANSI/AWS D1.1, American Welding Society, Miami.
- AWS (1998), *Symbols for Welding, Brazing and Nondestructive Examination*, AWS A2.4, American Welding Society, Miami.
- RCSC (2000), *Specification for High-Strength A325 and A490 Bolts*, Research Council on Structural Connections, Chicago, June 23.