Economical Structural Steelwork

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Fifth edition - 2009

AUSTRALIAN STEEL INSTITUTE

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specification. If tendering is involved, prices for the tender specification and for viable alternatives could be useful.

It is generally quite sufficient to nominate only the functional requirements plus compliance with an appropriate welding code, such as AS 1554, for satisfactory results. Standards are prepared for use as reference documents and it is not usually necessary to depart from them unless very good reasons exist.

Where welding is specified in accordance with an Australian Standard, it should be the one relevant to the service conditions,(e.g. specifying pressure vessel standards for a multi-storey office building is poor design). Fitness for service should be the sole criterion for the quality level specified and for the specification of the appropriate levels of inspection. Any departure from normal levels is likely to increase costs and should be called for only when really required.

7.4.3 WELDING INSPECTION

Fabrication costs are very sensitive to the required weld quality and the type and standard of inspection. Modern equipment and techniques for welding and testing of welds make it possible to provide near perfect weldments if so required. However, this also adds considerably to the cost. If such standards are not necessary, the benefits previously gained by careful economic design are frequently negated. It rests with the design engineer to determine the critical areas of a structure requiring close inspection and then to set a realistic standard for the inspector to follow.

In setting guidelines for the inspector, the best results are achieved by nominating the use of the Structural Steel Welding Code, AS 1554. This Standard is well understood by both fabricators and inspection organisations and usually results in a good job being achieved at a reasonable cost. A confusing and often expensive practice sometimes adopted is to rewrite some existing Standard clauses into the specification in an attempt to achieve a higher standard than that provided by the Standard. This should be avoided because it usually leads to anomalies and contractual problems.

Fitness for purpose should be the rule in setting inspection standards and AS 1554 provides realistic levels of both workmanship and inspection suited specifically for various weld quality levels required in structural fabrication.

7.5 Economical Design and Detailing

The essential requirement of weld design is that adequate structural performance be provided. Usually a variety of alternative methods of achieving this aim are available and the cost aspects of the alternatives need to be looked at.

The principal considerations in economical detailing of weldments are:

(a) Simplicity – details of welded attachments and details of end connections should be simple and consist of the fewest possible number of component parts.

(b) Weld volume – only the minimum required weld volume, as determined by structural calculations, should be specified.

(c) Accessibility – welding electrodes must be able to be positioned in such a way that good quality welding can be achieved without difficulty and without undue strain on the operator.

(d) Erection – proper detailing should allow for reasonable fit-up tolerances and weld preparations.

(e) Inspection – all welds should be located in positions so that visual examination and/or non-destructive testing can be carried out easily.

The following rules are suggested as basic to economical weld design and detailing (see also Refs 7.2 and 7.3):

(1) Design with welding in mind.

This requires an appreciation of the cost components in welding, the types of weld available, the types of processes and procedures available and their limitations.

(2) Do not specify oversize welds.

The most cost effective weld is the smallest weld that provides the required strength. It is good weld design practice to provide only that amount of welding which ensures that the welded fabrication can perform its intended function.

Specifying oversize welds can be harmful in two ways. Firstly, the cost is unnecessarily increased and secondly, oversize welds cause increased shrinkage forces which may lead to distortion.

As an example, an 8mm fillet is only 33% stronger than a 6mm fillet, yet the volume of weld metal is 78% higher (Table 7.1). Thus, the cost of production of a joint can be significantly increased, not only due to the increased volume of weld metal required but more importantly due to the increased time in welding the joint.

The only qualifying point that should be raised is that the minimum weld sizes required by AS 1554 have to be observed and hence some oversize welds may be unavoidable.

The 'weld all round' philosophy should be avoided as it can lead to unnecessary additional cost.

(3) Use welding judiciously when using it to reduce material mass.

If welding is used to reduce the amount of material (e.g. by splicing to change ange plate thicknesses or to provide stiffeners to a thin web in a three-plate girder), then be sure the cost of the welding is less than the cost saving in material cost. Weld metal costs many times more than parent material (somewhere from 50-100 times), and it is often cheaper to increase component mass so as to reduce weld metal volume.

(4) Keep the number of pieces to be welded to the minimum practicable.

7. Welding

A simple design with the fewest number of pieces is the most economic and often results in a better product.

(5) Remember the special effects of welding such as distortion (Ref. 7.2).

(6) Allow welding to be used to maximum advantage.

This particularly applies to allowing the fabricator to take advantage of high production processes, and in many cases may be best achieved by consultation with the fabricator. The detailing of a weldment can often restrict the fabricator to only the one process, and this may not always be the most suitable.

(7) Aim for as much workshop fabrication as possible.

(8) Keep in mind the economics of fillet welding (Clause 7.2.1).

Fillet welds are usually limited to 6mm leg size for most processes (notably manual metal arc), although with other processes, under certain conditions, a 10mm or larger single pass fllet weld is possible (for example a 20mm single pass fllet weld is possible using tandem submerged arc welding but such processes are not commonly used when welding short runs on most simple connections). Before specifying large fllet welds, the situation should be checked with the fabricator. Larger single pass fllet welds can be placed in the at natural vee position. If more than a single pass is required, the cost of the weld increases signiflcantly.

Single run continuous fllet welds are usually more economic than intermittent fllet welds of a larger size.

(9) Keep in mind the economics of butt welding (Clause 7.2.2).

Complete penetration welds need only be specifled when they are really required, and the use of partial penetration welds can reduce weld metal and give other gains which add up to an improvement in productivity. If complete penetration welds are demanded, the use of backing bars with welds from one side which do not need back gouging or turning of the work piece, may lead to improvement.

If selecting joint preparations, use prequalifled preparations (AS 1554) to avoid qualiflcation testing.

Select the smallest included angle consistent with achieving the desired penetration. Better still, specify only, say, ‘complete penetration butt weld’ (or specify acceptable alternative details) on the drawing and allow the fabricator to select the method he can do best and most economically.

(10) Use fllets in preference to butt welds wherever possible.

Butt welds usually involve edge preparation, which adds to costs, and as a result fllet welds are cheaper than butt welds up to about 16mm thickness of connected plates. (Other considerations, such as joints which may be subjected to fatigue, may dictate the use of a butt weld in preference to a less costly fllet weld.)

(11) Provide adequate access.

Another way the designer can signiflcantly help productivity is to ensure adequate access for welding. This is vital as it is essential to ensure always that the appropriate quality of weld can be made.

Examples of bad accessibility – together with suggested improvements are shown in Figure 7.6.

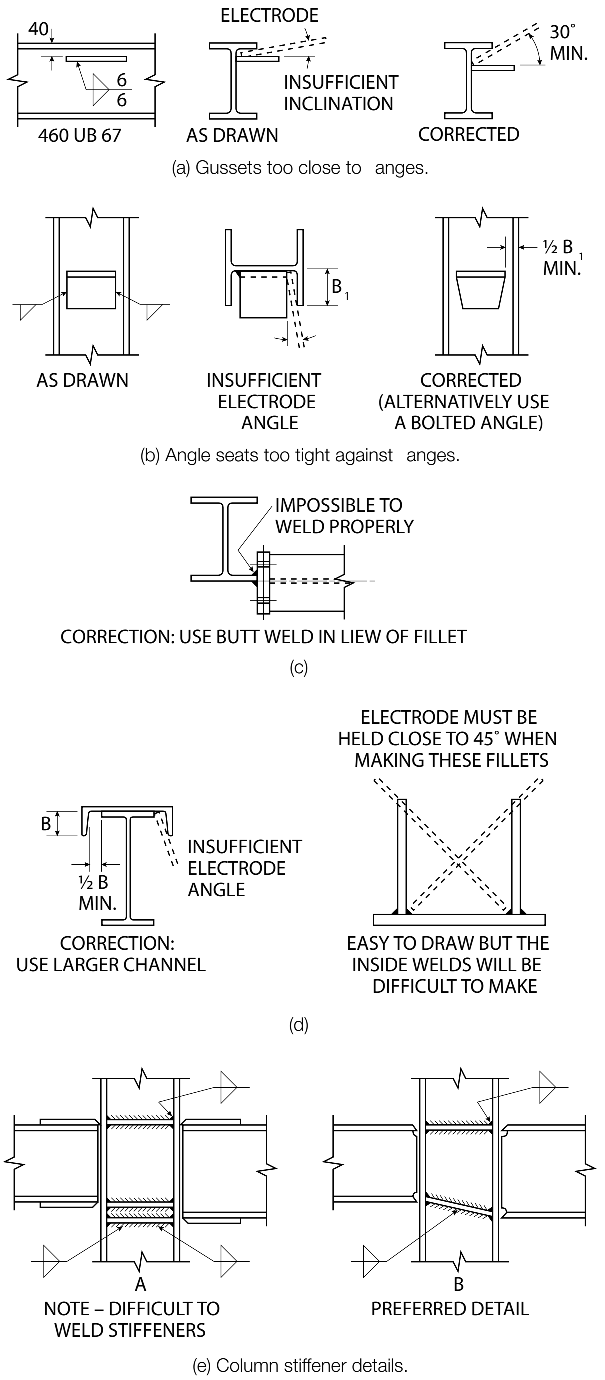

FIGURE 7.6: **Some common detailing faults resulting in poor accessibility for welding**

7. Welding

(12) Consider the method of fabrication.

Allow welds to be made in the downhand position wherever practicable. This can often be achieved by the fabricator using special jigs and positioners.

Always try to aid fabrication by designing to allow the maximum use of jigs and positioners – certainly try to make designs so that their use is not hampered.

(13) Avoid dictating the manner of making a welded joint.

The fabricator knows the best joint preparation and welding procedure for ease, economy and quality of joint using the facilities available. The designer who details the fabrication method must accept responsibility for any fabrication problems and extra cost.

Ensuring the method of fabrication is acceptable can be achieved by calling for compliance with a recognised Code or Standard (AS 1554) and requiring the proposed fabrication and welding procedure to be submitted for concurrence on important jobs.

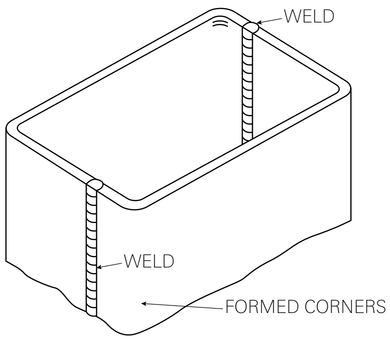

FIGURE 7.7: Use of bending to reduce welding and give clean corners

(14) Be receptive to alternative proposals. Be prepared to accept alternative welded joints/ details proposed by the fabricator which have clear advantages.

(15) Recognise the value of consultation with the fabricator.

(16) Use minimum number of joints by:

(mass – see item (3) and Figure 7.8.

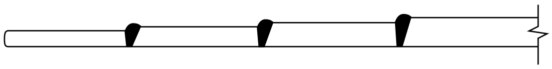

FIGURE 7.8: Beam flange with many different plate thicknesses – avoid when steel mass saved is less than 100 times mass of weld metal required

(17) Standardise joint details as much as practicable to reduce variety.

Different sized welds at a joint will require changes in current and electrode size by the operator. This causes lost time and a drop in the operating factor. Aim to have the minimum variety of weld sizes and types on a member or at a joint.

(18) Use sub-assemblies to give:

(a) Easier handling and positioning for downhand welding.

(b) Better access for welding.

(c) Less site welding and more shop welding (Figure 7.9).

(19) Use non-destructive testing judiciously.

The use of non-destructive testing of welds is very disruptive to the   ow of work and adds considerably to the cost of a structure. Much of this cost will be avoided if non-destructive testing is restricted to critical joints and carried out on a random basis only after careful development of weld procedures. Modern welding Codes encourage this approach.

(20) Test only where required.

Testing of welders and weld procedures for each job is expensive. Where practicable, consideration should be given to accepting welders and procedures approved by recognised authorities for other similar work.

(21) Specify weld quality consistent with service requirements.

Fitness for purpose should be the guiding rule in specifying weld quality. Higher quality specifled unnecessarily or for its own sake is wasteful and costly (see Clause 7.4.2).

Specify tolerances to limits consistent with the purpose of the weld. Adequate tolerances are necessary in order to allow for ease of flt-up.

(22) Avoid, as far as practicable, requiring turning of members to weld on other side.

Examples are:

(a) Avoid putting stiffeners on both sides of a plate girder web.

(b) Truss detailing which requires one side welding only (see Clause 8.4).

(c) Angle seat to column flange connections – a narrow seat in lieu of wide seat avoids turning the member (see Figure 7.10).

(23) Avoid joints which create difflcult welding procedures.

Joints which create difflcult welding procedures, such as two round bars side by side, acute angle intersections, etc., should be avoided. Such welds prove time-consuming and are of questionable quality (see Figure 7.11).

Such joints also cause difflculties with any post-weld treatments, (deslagging, brushing, grinding and corrosion protection).

(24) Consult 'Economic Design of Weldments' (Ref. 7.3) for further advice on ways to use welding effectively and economically.

7. Welding

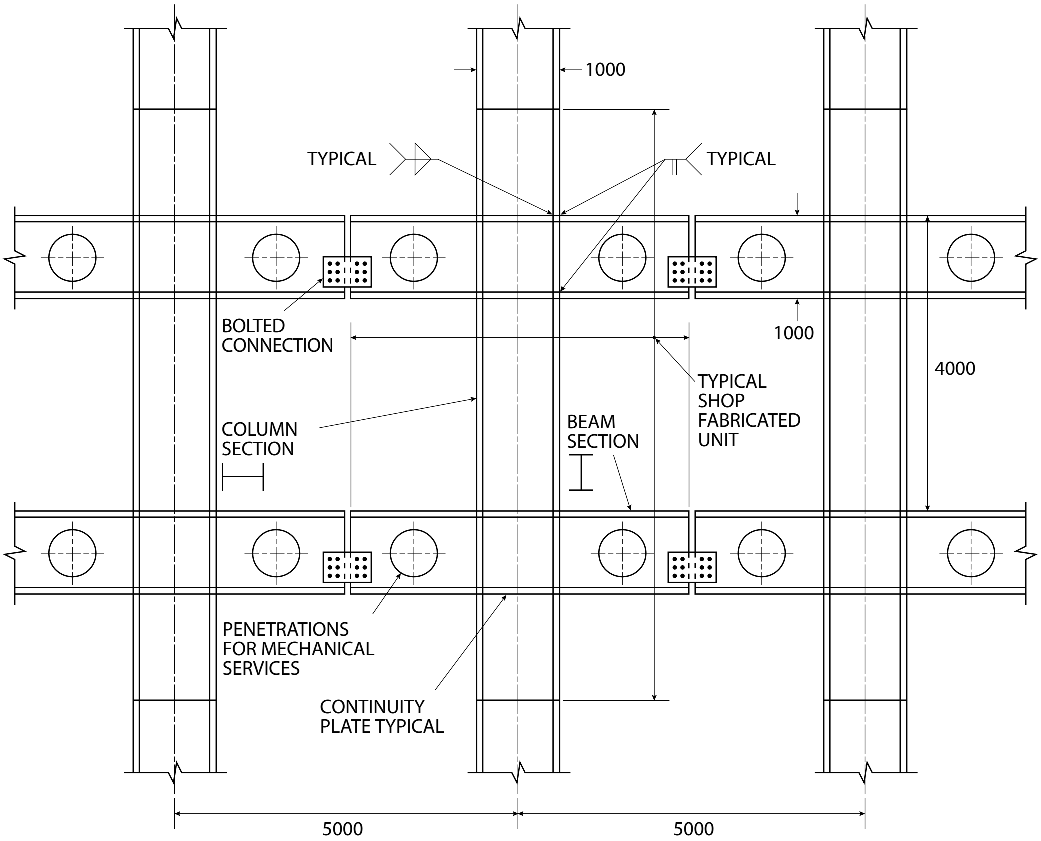

FIGURE 7.9 : Exterior column/spandrel sub-assemblies for Sears Tower, Chicago

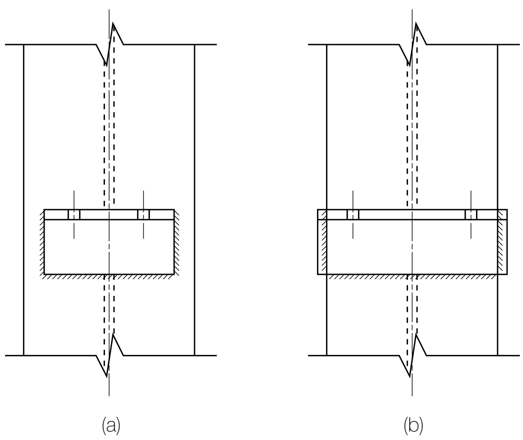

FIGURE 7.10: Angle seat detail – (a) preferable to (b)

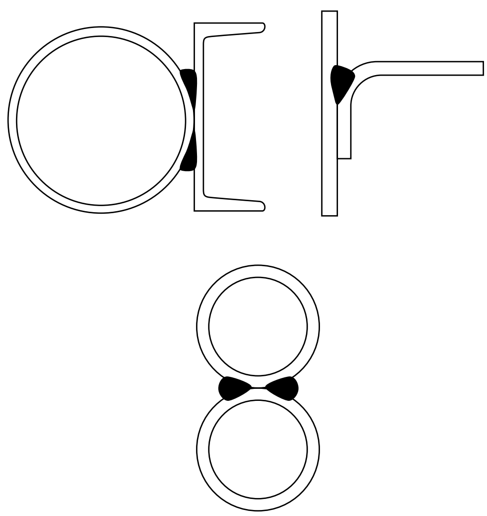

FIGURE 7.11: These joints are difficult to weld and the welds may be of questionable quality