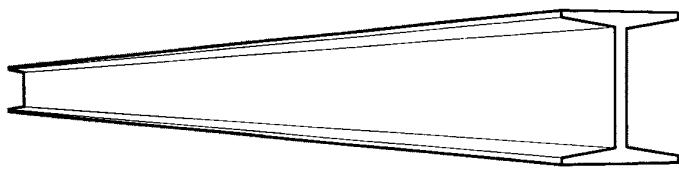




STRUCTURAL STEEL EDUCATIONAL COUNCIL



TECHNICAL INFORMATION & PRODUCT SERVICE

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Heavy Structural Shapes in Tension Applications

INTRODUCTION

On January 1, 1989 the American Institute of Steel Construction issued a supplement to both the 8th edition ASD Manual and the 1st edition LRFD Manual. The supplements covered procedures for welding Groups 4 & 5 structural shapes and sections built up from plates over 2" in thickness, subject to primary tension stresses.

These supplements have been part of the 9th edition 1989 ASD Specifications and apply equally to structures designed by the LRFD procedure. Recently, in many cases, the AISC provisions have been applied to sections other than those that are in Group 4 & 5, and to members other than those that

are subject to primary tensile stresses, and spliced using full penetration welds.

The application of the AISC provisions should be carefully assessed, since the requirements can lead to increased costs of material, fabrication, and inspection. Misapplying or altering the provisions can increase the cost of construction without necessarily increasing the reliability of the structure.

This TIPS is based on a Bethlehem Steel Corporation Technical Bulletin dated June, 1992 of the same title and the AISC Specifications. It is hoped that this will help clear up any misunderstanding that occur with design engineers regarding the use of heavy structural shapes in tension and spliced with full penetration welds.

BACKGROUND

In response to problems encountered in some situations with the use of heavy W-shapes and thick plates in non-column applications, the AISC Committee on Specifications has developed new provisions

covering material properties, splicing details, thermal cutting and welding of such shapes (References 1, 2 & 3).

The new provisions are applicable to ASTM A6/A6M Groups 4 and 5 rolled shapes

and to welded shapes built up from plates with thickness exceeding 2 in., if such rolled or welded shapes are subject to primary tensile stresses due to tension or flexure, and if they are spliced using full-penetration welds. The provisions include material toughness requirements for beam copes and weld access holes to facilitate welding operation and to minimize restraint, and fabrication requirements which include preheat for thermal cutting and for making groove-weld splices.

Solidified, but still hot, weld metal contracts significantly as it cools to ambient temperature. Shrinkage of large welds between elements, which are not free to move to accommodate the shrinkage, causes strains in the material adjacent to the weld that can exceed the yield point strain. In thick material, the weld shrinkage is restrained in the thickness direction, as well as in the width and length directions, causing triaxial stresses to develop that may inhibit the ability of ductile steel to deform in a ductile manner. Under these conditions, the possibility of brittle fracture increases.

When splicing ASTM Groups 4 and 5 rolled sections or heavy welded built-up members, the potentially harmful weld shrinkage strains can be avoided by use of bolted splices, fillet welded lap splices or a splice using a combination welded and bolted detail. However, details and techniques that perform well for materials of modest thickness usually must be changed or supplemented by more demanding requirements when welding thick material. Also, the provisions of Structural Welding Code AWS D1.1 are minimum requirements that apply to most structural welding situations.

When designing and fabricating welded splices of Groups 4 and 5 shapes and similar built-up cross-sections, special consideration must be given to all aspects of the welded splice detail. These are as follows:

- Notch-toughness requirements

shall be specified for tension members. AISC Specifications require that tension members of Group 4 & 5 structural shapes to be supplied with Charpy V-Notch testing and that the impact test shall meet a minimum average value of 20 ft. pounds absorbed energy at +70°F.

- AISC Specification J2.7 (ASD) requires pre-heating of Group 4 & 5 shapes and built-up members made of plates more than 2" thick to 350°F or greater when making groove weld splices.
- Generously sized weld access holes are required to provide relief from concentrated weld shrinkage strains by avoiding the close juncture of welds in orthogonal directions and to provide adequate clearance for the exercise of high quality workmanship in hole penetration, welding & ease of inspection. AISC Specifications state that weld access holes shall have a length from the toe of the weld preparation not less than 1 1/2 times the thickness of the material in which the hole is made. The height of the weld access hole shall be adequate for the deposition of sound weld metal and provide clearance for weld tabs.
- Thermally cut surfaces of beam copes and weld access holes in Groups 4 & 5 shapes and built up shapes over 2" thick shall be ground to bright metal and inspected by either magnetic particle or dye penetrant methods.
- Pre-heating for thermal cutting is required to minimize the formation of a hard surface layer. AISC Specifications require a pre-heat of 150°F for thermally cut edges of Group 4 & 5 shapes and built up shapes with material thicker than 2".

In addition to tension splices of truss chord members and tension flanges of flexural members, other joints fabricated of heavy sections subject to tension should be given special consideration during design and fabrication.

It is important to note that the provisions of notch toughness, grinding of thermally cut edges, etc. contained herein apply only to Group 4 & 5 structural shapes and built up sections with material thickness 2" or greater. Further, these provisions apply only to those heavy members subject to primary tensile stresses due to direct tension or flexure and spliced with full penetration welds. Examples are tension chords of trusses and beams in a ductile moment resisting space frame. Columns in which the dead load compression stresses exceed the tensile stresses due to lateral load flexure are normally not

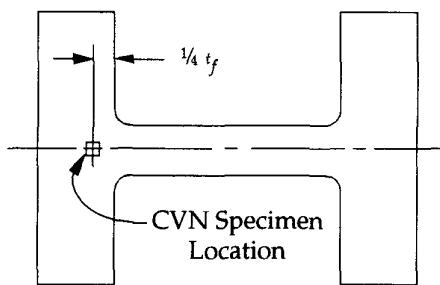
full penetration welded, do not go into net tension and are not governed by these provisions ($P/A \geq Mc/I$).

The September 1993 AISC Specification for LRFD construction adds some clarification to the welding requirements for Group 4 & 5 shapes with this sentence from Section A3.1c: The requirements need not apply to ASTM A6 Group 4 & 5 shapes and built-up members with thickness exceeding two inches to which members other than ASTM A6 Group 4 & 5 shapes are connected by complete-joint penetration welded joints through the thickness of the thinner material to the face of the heavy material. Additional requirements for joints in heavy rolled and built-up members are given in Sections J1.5, J1.6, J2.6, J2.7 and M2.2. This applies equally to structures designed by the ASD specifications.

AISC PROVISIONS: STRUCTURAL SHAPES

- For ASTM A6 Group 4 & 5 rolled shapes to be used as members subject to primary tensile stresses due to tension or flexure, *toughness need not be specified if splices are made by bolting.*
- If Group 4 & 5 rolled shapes are spliced using full penetration welds, the steel shall be specified in the contract documents to be supplied with Charpy V-Notch testing in accordance with ASTM A6, Supplementary Requirement S5. The impact test shall meet a minimum average value of 20 ft. lbs. absorbed energy at + 70°F and shall be conducted in accordance with ASTM A673 with the following exceptions:
 - a. The center longitudinal axis of the

specimens shall be located as near as practical to midway between the inner flange surface and the center of the flange thickness at the intersection with the web mid-thickness (see sketch below).



- b. Tests shall be conducted by the producer on material selected from a location representing the top of each ingot or part of an ingot used to produce the product represented by these tests.

PLATES

- For plates exceeding 2" thick used for built-up members with bolted splices and subject to primary tensile stresses due to tension or flexure, *material toughness need not be specified*.
- If such *members* are spliced using full-penetration welds, the steel shall be specified in the contract documents to

be supplied with Charpy V-Notch testing in accordance with ASTM A6, Supplementary Requirement S5. The impact test shall be conducted by the producer in accordance with ASTM A673, Frequency P, and shall meet a minimum average value of 20ft.-lb. absorbed energy at +70°F.

GENERAL

- The above supplementary toughness requirements shall also be considered for welded full-penetration joints other than splices in heavy rolled and built-up member subject to primary tensile stresses.
- The above supplementary toughness requirements need to be used in conjunction with good design and fabrication procedures. Additional AISC requirements include:
 - a. Splices in heavy sections
 - b. Beam copes and weld access holes

- c. Mixed weld metal
- d. Preheat for heavy shapes
- e. Thermal cutting

The reader is referred to the following sections of the AISC Specification contained in the 9th Manual ASD Sects. A3.1c, J1.7, J1.8, J2.6, J2.7 & M2.2 for further information. Also referenced is the September, 1993 Load and Resistance Factor Design Specification sections, A3.1c, J1.5, J1.6, J2.6, J2.7, & M2.2. The specifications for welding Group 4 & 5 shapes and built-up sections over 2" thickness apply equally to member designed by the ASD or LRFD methods.

GROUP 4 & 5 SHAPES

ASTM A-6 Section 3.10 defines hot rolled shapes into size groups from 1 to 5 based on web thickness. These groupings are shown in Table 2 of the AISC Manual of Steel Construction, both ASD & LRFD. It is noted again that the special welding procedure requirements contained in this TIPS apply

only to Group 4 & 5 shapes and welded shapes built up from plates over 2" thickness, subject to primary tension stresses and spliced with full penetration welds. A listing of Group 4 & 5 shapes is shown below.

GROUP 4	GROUP 5
W40x362 to 655 incl W36x328 to 798 incl W33x318 to 619 incl W30x292 to 581 incl W27x281 to 539 incl W24x250 to 492 incl W21x248 to 402 incl W18x211 to 311 incl W14x233 to 550 incl W12x210 to 336 incl	W36x848 W14x605 to 730 incl
SUMMARY	
<p>The AISC Specifications, both for ASD and LRFD speak to state-of-the-art knowledge of the practice of welding Group 4 & 5 structural shapes and built-up sections having material thickness 2" or greater subject to direct tension or tension due to flexure and spliced with full penetration welds.</p>	<p>Notch-toughness requirements, size of weld access holes and specification for pre-heating and treatment of thermally cut holes are covered in the specifications.</p>
<p>The AISC Specifications provide only part of what is needed to minimize the potential for failure. They must be used in conjunction with good design and fabrication procedures.</p>	
REFERENCES	
<p>1) Bethlehem Steel Corp. Technical Bulletin, "Use of Heavy Structural Shapes in tension Applications," dated June 1992.</p>	<p>2) AISC "Specification for Structural Steel Buildings," June 1989.</p> <p>3) AISC "LRFD Specification for Structural Steel Buildings," September 10, 1993.</p>
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