# WHAT'S NEW IN THE AISC 1999 LRFD SPECIFICATION FOR STRUCTURAL STEEL BUILDINGS

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The American Institute of Steel Construction (AISC) will welcome the new millennium with the introduction of the third edition of the Load and Resistance Factor Design Specification for Structural Steel Buildings (LRFD Specification) (1) to supersede the 1993 LRFD Specification (2). The AISC Specification has come a long way since the first one was introduced in 1923 with a total length of nine pages. Originally developed to create standards of practice in the steel industry, subsequent revisions of the specification have reflected both advances in research and changes in design practice. The current state-of-the-art design method for steel buildings is Load and Resistance Factor Design (LRFD), which was introduced by AISC in its 1986 Specification (3). The 1999 LRFD Specification will contain several updated provisions and some new ones as well. A slight change in the overall format will also be apparent to regular users. Some of the revisions discussed were issued by AISC in the January 30, 1998, Supplement No. 1 (4).

The purpose of this paper is to highlight the major changes and new provisions of this 1999 AISC Specification.

## What's New and Different

Among the new topics included in the 1999 LRFD Specification are stability bracing and evaluation of existing structures (Chapter N). These stability bracing requirements can be used in lieu of a second order analysis that takes into account initial out-of-plumbness of the structure or out-of-straightness of the member. The criteria presented are based primarily on work in the late 50's by George Winter at Cornell University and more recent studies by Joseph Yura at the University of Texas. This section gives equations for minimum brace strength and stiffness for frames, columns, and beams, necessary to ensure member design strengths are attained. The formulations are a function of the unbraced length, assuming K equal to one. In addition to strength and stiffness equations, other issues are addressed such as brace spacing and attachment. Two general types of bracing systems are considered, relative and nodal. Relative bracing is applied relative to another bracing location, i.e. diagonal bracing or shear walls. Nodal bracing controls displacement only at the particular brace point, i.e. cross bracing between two adjacent beams (see Figure 1, which is Figure C-C3.1 from the Commentary (1)).

Another topic never before addressed in the AISC Specification is the evaluation and repair of existing structures. This is in response to the aging infrastructure and the desire of owners to renovate instead of demolish. The new Chapter N presents procedures for evaluating the strength and stiffness of existing buildings by structural analysis, gravity load testing, or a combination of the two, as required by the Engineer of Record or the contract documents. The Chapter is applicable only to structures under static loading. Guidelines for material properties testing, such as tensile properties, chemical composition, base metal notch toughness, and filler metal are also included. The final section outlines the format for an evaluation report.

Aside from these two completely new design issues, the 1999 LRFD Specification will include some reorganized sections to present the information in a more concise manner as well as some revisions to existing design provisions. Section D3, Pin-Connected Members and Eyebars, and Section E4, Built-Up Members, are now presented in outline form with detailing requirements listed separately from design strength provisions.

Two new structural steels are now approved for use in the Specification, ASTM A913 and A992. The

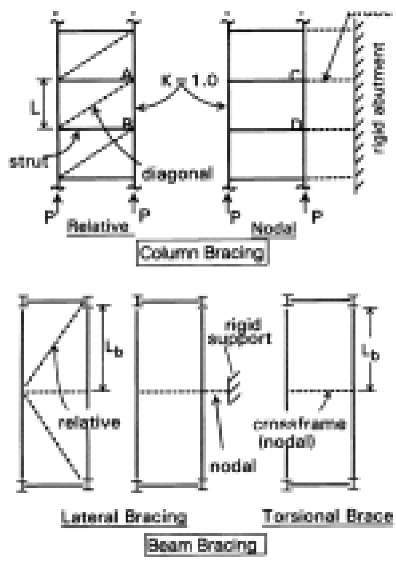


*Fig. 1. Types of Bracing*

former is High-Strength Low-Alloy Steel Shapes of Structural Quality, Produced by Quenching and Self-Tempering Process (QST). This material provides a specified Charpy V-notch value of 40 ft-lb. at 70° F. The ASTM A992 designation, entitled Steel for Structural Shapes for Use in Building Framing, was given to the shape material described in AISC's Technical Bulletin 3 (A572 Gr. 50 with special requirements). The A992 Grade 50 provides for a better-defined structural steel through a maximum yield strength limit of 65 ksi, maximum yield to ultimate strength ratio of 0.85 and carbon equivalent criteria for weldability.

Chapter I, Composite Members, contains new criteria pertaining to the application of shear connectors in concrete-encased steel columns and beams. AISC Steel Design Guide Series 6, "Load and Resistance Factor Design of W-Shapes Encased in Concrete", indicates that shear connectors are required to provide load transfer between a steel column and the surrounding concrete. In response to this, the 1999 LRFD Specification gives equations for the required force to be transferred by the shear connectors for the case where the external force is applied directly to the steel, or directly to the concrete. An important revision to note on this subject is the increase in the resistance factor for bearing, $\phi_B$, from 0.60 to 0.65. This is for consistency with Appendix C of the latest versions of ACI 318 and ACI 318M. The design strength of concrete-encased beams where shear connectors are provided is given in a new paragraph where the design flexural strength is based on the plastic stress distribution of the composite section.

Additional modifications included in Chapter I pertain to general composite column design and composite slabs when a single shear connector is placed in a deck rib oriented perpendicular to the steel beam. In this case, the new Specification places an upper limit on the reduction factor on shear connector strength to 0.75, instead of 1.0. This is in response to recent and ongoing research that indicates the previous method of calculating the strength for a shear connector is unrealistic when there is a single connector in a rib. Because composite beam strength has a nonlinear dependency on shear force transfer, the flexural member capacity will be much less affected for the higher ranges of composite action. In calculations for composite column design strength, the specified minimum yield stress of the steel components is now limited to 60 ksi (formerly 55 ksi).

Some of the important new provisions appearing in Section J2, Welds, of the 1999 LRFD Specification are a new length reduction factor for fillet welds, updated details for fillet weld terminations, and filler metal requirements. The new length reduction factor applies to "end-loaded" fillet welds. The new term "end-loaded" refers to longitudinal fillet welds parallel to the applied load and designed to transmit load to the end of an axially loaded member, i.e. longitudinally welded lap joints at the end of axially loaded members or welds attaching bearing stiffeners. A length reduction factor, $\beta$, is applied to weld lengths greater than 100 times the weld size. The $\beta$ equation is consistent with the Eurocode 3 standard, which is based on finite element studies and research performed on this subject over many years. The other revision appearing in Section J2 deals with fillet weld terminations. Welding detail characteristics are more clearly stated for lap joints, connections and elements undergoing cyclic forces, connections requiring flexibility of outstanding legs, fillet welds joining transverse stiffeners to plate girders, and fillet welds occurring on opposite sides of a common plane. An expanded commentary also includes visual aids for further explanation. Finally, filler metal requirements are given for certain complete-joint-penetration groove welded T and corner joints and splices of heavy shapes with tension normal to the effective area. In the special cases given in new Section J2.6, the filler metal requires a specified Charpy V-notch toughness of 20 ft-lbs at 40°F. Alternatively, the lower design strength condition for partial-joint-penetration groove welds governs.

Most of the revisions to the bolt provisions of the new Section J3, Bolts and Threaded Parts, are consistent with the provisions in the Research Council on Structural Connections' Load and Resistance Factor Design Specification for Structural Joints Using ASTM A325 or A490 Bolts (RCSC Specification) (5). Revisions include the following topics: snug-tight bolting, combined tension and shear of bearing-type connections, design of slip-critical connections, and bearing strength. Previously limited to only statically loaded shear connections, snug tightening is now permitted for ASTM A325 bolts in tension or combined shear and tension static applications. This reflects recent research that demonstrated the ultimate strength of ASTM A325 bolts under these conditions is not affected by the level of pretension present. For bearing-type connections loaded in combined tension and shear, the coefficients in the design equations have been modified slightly. It should be noted that the RCSC Specification uses an elliptical solution, while AISC has both a straight-line approximation of this in the main Specification and the elliptical solution in an Appendix. Thus, the designer can select which approach to use. The design strengths for slip resistance in slip-critical connections at factored loads has been more conveniently relocated to the main body of the Specification, exchanging places with the provisions for design at service loads which are now in the Appendix. The mean slip coefficient, $\mu$, for Class C (galvanized) faying surfaces in slip-critical connections has also been reduced to 0.35. For slip-critical connections subject to combined tension and shear, the multiplier that accounts for the effect of the tensile component on slip resistance has been slightly modified to be consistent with the RCSC Specification. A subject affecting both bearing-type and slip-critical connections is bearing strength. This section has been updated based on recent research and the basis of the bearing calculation has been modified to the clear distance to an edge or between fasteners, rather than on center-to-edge and center-to-center distances. The resulting design strengths are largely unaffected by this modification, except for very small edge distances and spacings.

In the 1999 LRFD Specification, Appendix K3, Design for Cyclic Loading, replaces the old Appendix K3, Fatigue. The past method of fatigue design relied upon multiple tables consisting of cycles of loading, stress categories, design stress ranges, and illustrative examples.

**TABLE A-K3.1**
Fatigue Design Parameters

| Description | Stress Category | Constant $C_f$ | Threshold $F_{TH}$ ksi (MPa) | Potential Crack Initiation Point |
|---|---|---|---|---|
| **SECTION 1 – PLAIN MATERIAL AWAY FROM ANY WELDING** | | | | |
| 1.1 Base metal, except non-coated weathering steel, with rolled or cleaned surface. Flame-cut edges with surface roughness value of 1 000 μin. (25 μm) or less, but without re-entrant corners. | A | $250 \times 10^8$ | 24 (165) | Away from all welds or structural connections |

**TABLE A-K3.1** (cont'd)
Fatigue Design Parameters

**Illustrative Typical Examples**

**SECTION 1 - PLAIN MATERIAL AWAY FROM ANY WELDING**

1.1 and 1.2


Fig. 2. Excerpts from Table A-K3.1.

This has been replaced by a new format where one table presents the situation description, the stress category, variables for the applicable equation, the potential crack initiation point and pertinent illustrative examples for each situation (see Figure 2 which is an excerpt from Table A-K3.1 of the Specification (1)). One new detail included is tension loaded plate elements connected at their end by transverse groove or fillet welds. New criteria are also included for fatigue resistance of non-pretensioned bolts subject to applied tension, such as used in hanger rods or anchor rods. A similar format and consistent criteria is being developed for the AWS code.

One visible change throughout this version of the AISC LRFD Specification is the conversion to dual units format, U.S. Customary units and SI (metric) units. AISC introduced a metric conversion of the 1993 LRFD Specification in 1994. The 1999 LRFD Specification will combine the two by providing metric equivalents in parentheses following the U.S. Customary unit value. The metric conversions are based on ASTM E380, Standard Practice for Use of the International System of Units (SI). Equations are also presented in dual format. Where possible, they are non-dimensionalized by factoring out material constants, such as $E$ and $G$; otherwise the metric version is listed separately. This is in response to an ongoing domestic movement to use the metric system of measurement, largely led by government agencies, as well as broader interest in relating and participating in the international arena, which is almost exclusively based on the SI system.

This is only a sampling of the major changes you will find in the AISC 1999 LRFD Specification. The reader is referred to the printed document for the exact and complete design requirements and commentary. Work is underway on the 3rd Edition Load and Resistance Factor Design Manual of Steel Construction, which will be introduced in late 2001.

References

1. Load and Resistance Factor Design Specification for Structural Steel Buildings, AISC, Chicago, IL, 1999.

2. Load and Resistance Factor Design Specification for Structural Steel Buildings, AISC, Chicago, IL, 1993.

3. Load and Resistance Factor Design Specification for Structural Steel Buildings, AISC, Chicago, IL, 1986.

4. Supplement No. 1 to the Load and Resistance Factor Design Specification for Structural Steel Buildings, AISC, Chicago, IL, 1998.

5. Load and Resistance Factor Design Specification for Structural Joints Using ASTM A325 or A490 Bolts, Research Council on Structural Connections, AISC, Chicago, IL, 2000.

**TECHNICAL BULLETIN 3** **MARCH, 1997**

# SHAPE MATERIAL
## (ASTM A572 Gr 50 with special requirements)

As announced, effective May 1, 1997, structural steel shapes will be commercially available with special requirements. Please consult your steel supplier for specifics.

Steel shapes ordered to this technical bulletin shall conform to the following:

1. Meet all requirements of ASTM A572/A572M-94c *Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel* Grade 50;

2. The steel shall be made to a practice producing nitrogen not greater than 0.012% or steel shall be made to a practice producing nitrogen not greater than 0.015% and nitrogen binding elements shall be added;

3. Chemical Requirements:

   The heat analysis shall conform to the requirements in Table 1;
   Test reports shall include the chemical analysis for tin for information. When the amount of tin is less than 0.02%, the analysis may be reported as "<0.02%";
   The carbon equivalent (CE) shall not exceed 0.50% except steel shapes not included in Groups 4 or 5 shall be supplied with a maximum of 0.45% if the carbon content is greater than 0.12%. The carbon equivalent shall be calculated using the following formula:

   $$CE= C +(Mn + Si)/6 + (Cu + Ni) / 15 + (Cr + Mo + V + Cb)/5$$

TABLE 1 Chemical Requirements

| Element | Composition, % |
|---|---|
| Carbon, max | Refer to ASTM A572 |
| Manganese | 0.50 - 1.50[a] |
| Silicon, max | Refer to ASTM A572 |
| Vanadium[b] | Refer to ASTM A572 |
| Columbium[b] | Refer to ASTM A572 |
| Phosphorous, max | 0.035 |
| Sulfur, max | 0.045 |
| Element | Composition, % |
| Copper, max | 0.60 |
| Nickel, max | 0.45 |
| Chromium, max | 0.35 |
| Molybdenum, max | 0.15 |

[a] Minimum manganese for Group 1 shapes is 0.30%. The ratio of manganese to sulfur shall not be less than 20 to 1.

[b] Columbium plus vanadium is not to exceed 0.15% maximum. Nitrogen when added as a supplement to vanadium shall be reported and the minimum ratio of vanadium to nitrogen shall be 4 to 1.

4. Tensile Requirements:

| | |
|---|---|
| Yield Point, ksi [Mpa] | 50 - 65 [345 - 450] |
| Yield to Tensile Ratio, max | 0.85 |

**SUPPLEMENTARY REQUIREMENTS**

These requirements shall not apply unless specified in the order.

Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A6/A6M. Those that are considered suitable for use with this specification are listed by title:

S1. Vacuum Treatment

S2. Product Analysis

S5. Charpy V-Notch Impact Test

S8. Ultrasonic Examination

S14. Bend Test

**ADDED SUPPLEMENTARY REQUIREMENTS**

In addition, the following optional supplementary requirements are also suitable for use with this specification.

S79. Maximum Tensile Strength
S79.1 The maximum tensile strength shall be 90 ksi [620 Mpa].

S91. Fine Austenitic Grain Size
S91.1 The steel shall be killed with a fine austenitic grain size.

SX3. Charpy V-Notch Impact Test for Group 4 and 5 Structural Shapes

SX3.1 When Group 4 and 5 structural shapes are used as members subject to primary tensile stress and when such members are spliced using full penetration welds, the steel shall be impact tested in accordance with Specification ASTM A6, supplementary requirement S5, modified in accordance with SX3.2.

SX3.2 Charpy V-Notch impact tests shall be conducted in accordance with Specification ASTM A673/A673M with the following exceptions for Group 4 and 5 rolled shapes:

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 Fig. 1).

SX3.3 The frequency of testing shall be Frequency P in Specification ASTM A673/A673M with the following exception for rolled shapes produced from ingots:

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

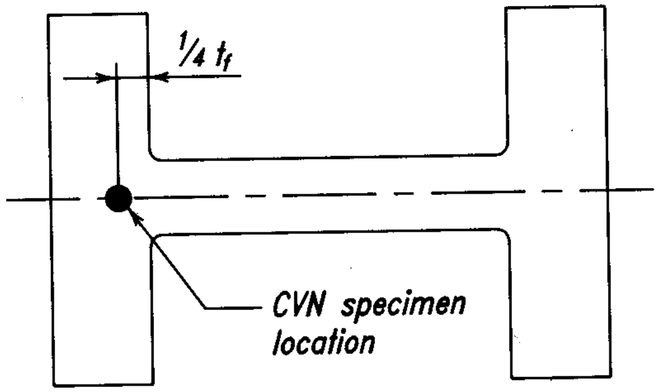


*Fig. 1 Location from which Charpy impact specimen shall be taken for Group 4 and 5 structural shapes.*

SX3.4 The test result shall meet a minimum average value of 20 ft-lb [27J] absorbed energy at +70°F [+21°C] if the steel is intended for ordinary use in buildings such as static loading. For unusual applications such as dynamic loading, highly restrained connections, low temperature or any combination of these conditions, the purchaser should consider more restrictive Charpy V-notch requirements for specification in the contract documents.