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North American Specification for Design of Cold-Formed Steel

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Abstract

For over fifty years, the American Iron and Steel Institute has published the widely used *Specification for the Design of Cold-Formed Steel Structural Members*. Recently, as a result of collaborative efforts with representatives of Canada and Mexico, the *AISI Specification* was expanded into a new document for use in all three countries. Now known as the *North American Specification for the Design of Cold-Formed Steel Structural Members*, the new edition supersedes the previous *AISI Specification* and the Canadian *S136 Standard*. This paper reviews the differences between the previous *AISI Specification* and the new *North American Specification*. The basic core document consists of Chapters A through G, while country specific issues are addressed in three separate appendices. The appendices include items of a broad nature, such as provisions for the design method to be used, the reference source for loads and load combinations, and other references that are country specific. The appendices also include country specific technical provisions where full agreement between the three countries was not reached. Efforts will be made to minimize these differences in future editions.

Introduction

The premier edition of the 2001 *North American Specification for the Design of Cold-Formed Steel Structural Members* (AISI, 2001), as its name implies, is intended for use throughout Canada, Mexico and the United States. It supersedes the previous editions of the *Specification for the Design of Cold-Formed Steel Structural Members*, published by the American Iron and Steel Institute (AISI, 1996 and AISI, 1999) for over 50 years, and the *S136 Standard for Cold Formed Steel Structural Members* published by the Canadian Standards Association (CSA, 1994) for many years. This paper summarizes the technical changes between the North American *Specification* and the 1996 AISI *Specification* with the 1999 *Supplement*. Research that led to many of these changes is referenced in the *Commentary* to the North American *Specification*.

Background

The North American *Specification* is the result of a collaborative effort of the American Iron and Steel Institute Committee on Specifications, the Canadian Standard Association S136 Committee on Specifications, and Camara Nacional de la Industria del Hiero y del Acero (CANACERO) in Mexico. The development of the *Specification* was coordinated through the North American Specifications Committee, which contained three members each representing AISI's Committee on Specifications, CSA's S136 Committee, and

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Mexico's CANACERO. The committee typically met twice a year beginning in 1995. The then current AISI *Specifications* were used as the core document to work from. New or revised provisions were integrated therein over the last several years to meet the requirements of all three countries, which approved the final consensus document.

Specification Format

Since the *Specification* is intended for use in Canada, Mexico and the United States, it was necessary to develop a format that would facilitate the allowance of unique requirements in each country. This resulted in a format that contained a basic document, Chapters A through G, intended for use in all three countries, and three country specific appendices, A through C. The appendices include items of a broad nature, such as provisions for the design method to be used, the reference source for loads and load combinations, and other references that are country specific. The appendices also include country specific technical provisions where full agreement between the three countries was not reached. Efforts will be made to minimize these differences in future editions.

This *Specification* provides an integrated treatment of Allowable Strength Design (ASD), Load and Resistance Factor Design (LRFD), and Limit States Design (LSD). This is accomplished by including the appropriate resistance factors (ϕ) for use with LRFD and LSD and the appropriate factors of safety (Ω) for use with ASD.

Summary of Global Changes

1. Applicability. The Specification was expanded to apply to Canada and Mexico as well as the United States. Most technical provisions were adopted as common to the three countries. Others that are country specific were grouped in lettered Appendices that apply only to a specific country: Appendix A – United States, Appendix B – Canada, and Appendix C – Mexico.

2. Design Methods. Three design methods are recognized: ASD – now termed Allowable Strength Design, LRFD – Load and Resistance Factor Design, and LSD – Limit States Design. The use of ASD and LRFD is limited to the US and Mexico; LSD is limited to Canada. LRFD and LSD are essentially the same except for differences in nomenclature, load factors, load combinations, and target reliability indexes. Equivalent LSD terminology is shown in brackets throughout the *Specification*. Since different target reliabilities are used in the US and Canada, the resistance factors applicable to the US and Mexico differ from the ones for Canada throughout the *Specification*.

3. Units. Although most of the *Specification* provisions are presented in dimensionless form, three systems of units are shown where this was not possible: US customary (kilo-pound, inch), SI (Newton, mm), and MKS (kg, cm), which is used in Mexico.

4. Fatigue. Chapter G was added to provide for the design of members and connections subjected to cyclic loading (fatigue).

Summary of Technical Changes

1. A1.1 Scope. For configurations where it is not possible to calculate the strength or stiffness of members and connections from the provisions of Chapters B through G, the designer now has two options: (1.) Tests in accordance with Chapter F or (2.) Rational engineering analysis. A set of safety factors and resistance factors for members and connections is given for use with rational analysis.

2. A1.2 Terms. The terminology was updated and expanded.

3. A2.1 Applicable Steels. References to ASTM specifications were updated.

4. A3 Loads. These provisions are given in country specific provisions. For the US, the provisions defer loads and load combinations to the applicable building code or ASCE 7, and no load combinations are given in the document. Also, in A4.1.2, the use of the 0.75 factor on load combinations for ASD is limited to "the combined effect of two or more loads, excluding dead load." This has the effect of eliminating the traditional 1/3 allowable stress increase on load combinations that include wind. Specific design requirements for ponding were deleted as they are covered by the building codes.

5. B2.1 Uniformly Compressed Stiffened Elements. In determining effective width, the slenderness factor λ was expressed in terms of the elastic critical buckling stress F_{cr} as $\lambda = \sqrt{f / F_{cr}}$

6. B2.3 Webs and Other Stiffened Elements Under Stress Gradient. Different expressions are now given for determining the plate buckling coefficient k depending on the value of h_o/b_o, where h_o is the out-to-out web dimension and b_o is the out-to-out width of the compression flange. The expressions previously used were based on the assumption that the flanges restrained the web, but it was determined that this is unconservative when $h_o/b_o > 4$. Therefore, new expressions were added for the case where $h_o/b_o > 4$ and the previous equations retained for the case where $h_o/b_o \leq 4$. Also, the stress ratio ψ is now defined as an absolute value, so some of the signs in the equations have changed.

7. B4.1 Uniformly Compressed Elements with One Intermediate Stiffener. The expression for k was revised to eliminate a discontinuity in the previous expressions.

8. B4.2 Uniformly Compressed Elements with an Edge Stiffener. The expressions for k were revised to eliminate a discontinuity in the previous expressions.

9. B5 Effective Widths of Stiffened Elements with Multiple Intermediate Stiffeners or Edge Stiffened Elements with Intermediate Stiffeners. Based on the results of new research, this section was completely rewritten and expanded to include both Stiffened Elements with Multiple Intermediate Stiffeners and Edge Stiffened Elements with Intermediate Stiffeners. Stiffened Elements with Multiple Intermediate Stiffeners covers both a general case (arbitrary stiffener size, location and number) and a specific case for 'n' identical stiffeners, equally spaced. In the approach adopted, k is determined as the lesser of the value calculated for both local buckling, in which the stiffener does not move, and distortional buckling, in which the stiffener buckles with the entire plate.

10. C2 Tension Members. The provisions for tension members are given in the appendices. For the U.S., the nominal tensile strength is taken as the smallest value for the limit states of (a) yielding in the gross section, (b) fracture in the net section away from connections (not previously included), and (c) fracture in the effective net section at the connection, which is treated by reference to Chapter E.

11. C3.2.1 Shear Strength of Webs Without Holes. The coefficients in the equations were changed slightly after recalibration. A single value was adopted for the safety factor and the resistance factor, instead of different values in different web slenderness ranges as in the past.

12. C3.4.1 Web Crippling Strength of Webs without Holes. In the previous *Specification*, separate equations were given for the web crippling strength under different conditions. In the new *Specification*, as a result of additional research, a single consistent unified equation was adopted for the web crippling strength under all conditions.

13. C3.5 Combined Bending and Web Crippling Strength. In the ASD interaction equation for the support point of two nested Z-shapes, the coefficients were slightly revised as a result of the changes made in the web crippling equation.

14. C3.6 Stiffeners. This section was previously located in B6.

15. C4.3 Point-Symmetric Sections. A new section was added to indicate how the elastic buckling stress should be determined for point-symmetric sections.

16. C4.5 Built-Up Members. This section was added to provide a general means of calculating the axial compressive strength of two sections in contact. It replaces a previous section (D1.1a). An equation is given for calculating a modified slenderness ratio, an approach that is used in AISC specifications and others.

17. C5.2 Combined Compressive Axial Load and Bending. For singly-symmetric unstiffened angles with unreduced effective area, the combined compressive and bending check does not need to consider the additional moment PL/1000 as

required in the previous editions. This requirement is, however, still needed for other angle sections.

18. D3.2.2 Neither Flange Connected to Sheathing. This section specifies the force for which intermediate braces for C- and Z-sections must be designed. A correction was made in the expression for Z-section bracing.

19. E2 Welded Connections. The factors of safety for welded connection design were recalibrated to agree with the resistance factors.

20. E3.2 Tension Member Shear Lag Effect in Bolted Members. These provisions are given in the appendices. For the U.S., the equations for the fracture stress on the net section were revised to reflect the results of additional research. Eqs. E3.2-2 and E3.2-4, which consider the strength reduction due to out-of-plane deformation, are limited to connections with a single row of bolts perpendicular to the force.

21. E3.3.1 Strength Without Consideration of Bolt Hole Deformation. The equation for bearing strength was revised to reflect the results of additional research.

22. E4.2 Minimum Edge and End Distance. For screw connections, the minimum distance from the center of a fastener to the edge of any part was reduced from 3 diameters to 1.5 diameters. However, if the end distance is parallel to the force, the shear strength per screw is subject to a strength reduction.

23. E4.3.3 Shear in Screws. The nominal shear strength was limited to 0.80 times that reported by the manufacturer.

24. E4.4.3 Tension in Screws. The nominal tension strength was limited to 0.80 times that reported by the manufacturer.

Conclusions

The development of the *North American Specification for the Design of Cold-Formed Steel Structural Members* provides a unified document that can be used throughout Canada, Mexico, and the United States. Even though there were a few areas where full agreement between the three countries was not reached, the publication of this document is a notable achievement, made possible only by the continuing spirit of cooperation among representatives of the three countries. Efforts will be made in future editions to minimize the remaining technical differences.

Acknowledgements

The consensus committees responsible for developing these provisions provide a balanced forum including representatives from steel producers, fabricators, users, educators, researchers, and building code officials. They are composed of engineers with a wide range of experience and high professional standing from Canada, Mexico, and the

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