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AISI Standards Developed and Updated in 2015 and 2016

Helen Chen

Roger Brockenbrough

Richard Haws

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By Helen Chen[1], Roger Brockenbrough[2], Richard Haws[3]

Abstract

During 2015 and 2016, AISI developed framing standards were consolidated and updated, the North American Specification was updated and reorganized in format, and two new test standards were published. This paper provides an overview of the reorganized standards and major changes, and a brief introduction to the newly developed test standards.

Introduction

In 2015, AISI cold-formed steel framing standards, AISI S200, S210, S211, S212, S213, and S214 (references 1 to 6), were consolidated into one standard AISI S240, *North American Standard for Cold-Formed Steel Structural Framing*. This new standard includes design provisions for wall, floor and roof systems, lateral force-resisting systems, as well as framing components such as trusses and headers.

The seismic design provisions in AISI S213 and AISI S110 (7) were consolidated into AISI S400, *North American Standard for Seismic Design of Cold-Formed Structural Systems*, which includes design provisions for shear walls, strap braced walls, special bolted moment frames, and diaphragms.

AISI S100, *North American Specification for the Design of Cold-Formed Steel Structural Members*, was updated and reorganized to be parallel in format with ANSI/AISC 360, *Specification for Structural Steel Buildings* (8). This reorganization should certainly help more engineers to get familiar with cold-formed steel design and provide a better layout for future standard development.

[1] Manager, Construction Standards Development, American Iron and Steel Institute, Washington, DC.
[2] President, R. L. Brockenbrough & Associates, Pittsburgh, PA.
[3] Commercial Solutions Director, Nucor Buildings Group, Denton, TX.

More information on AISI standard reorganizations may be found in a recent paper (9), *Enabling Cold-Formed Steel System Design Through New AISI Standards*.

During 2015 and 2016, the following AISI standards were updated:

AISI S220-15, *North American Standard for Cold-Formed Steel Framing—Nonstructural Members*

AISI S230-15, *Standard for Cold-Formed Steel Framing—Prescriptive Method for One- and Two-Family Dwellings*

AISI S310-16, *North American Standard for the Design of Profiled Steel Diaphragm Panels*

And the following two new test standards were published:

AISI S915-15, *Test Standard for Through-the-Web Punchout Cold-Formed Steel Wall Stud Bridging Connectors*

AISI S916-15, *Test Standard for Cold-Formed Steel Framing—Nonstructural Interior Partition Walls With Gypsum Board*

It should be noted that the newly developed and updated AISI standards published in 2015 refer to AISI S100-12 (10), not AISI S100-16, due to the sequencing of the documents in the standard development schedule.

In the following sections, the updated standards will be briefly reviewed and the new standards will be introduced.

1. AISI S240-15, North American Standard for Cold-Formed Steel Structural Framing

AISI S240-15 was developed based on previously published standards AISI S200, S210, S211, S213, and S214, and is for design and installation of cold-formed steel framing gravity systems and lateral force-resisting systems. The seismic lateral force-resisting systems and diaphragms must be designed in accordance with AISI S400 where increased seismic performance is required.

To help users to quickly locate the design provisions in the new standard, a section reference between AISI S240 and the previous standards is provided. The new standard includes the following chapters:

Chapter A, General. This chapter outlines the scope: the standard is for design and installation of cold-formed steel framing (a) floor and roof systems, (b) structural walls, (c) shear walls, strap braced walls and diaphragms to resist in-plane lateral loads and (d) trusses for load-carrying purposes in buildings. The chapter also includes definitions for terms used in the standard, list of materials applicable for the framing members, corrosion protection requirements, framing products and reference documents. Some major changes/additions as compared to the previous framing standards include:

(a) The limitation of framing member specified minimum base steel thickness to 118 mils (0.1180 inches or 2.997 mm) was eliminated.
(b) Manufacturing tolerances of flange width and stiffening lip length were added for structural members. These tolerances are consistent with ASTM C645 and ASTM C955.

Chapter B, Design. All the design provisions for the cold-formed steel framing systems are provided in this chapter. The major additions include:

(a) For curtain wall systems, the standard permits the use of the bracing combination of sheathing attached to one side of the wall stud and discrete bracing spaced within 8 ft (2.44 m) for the other flange. The curtain wall stud's nominal strength [resistance] should be determined in accordance with AISI S100.
(b) For cold-formed steel roof or floor diaphragms with maximum aspect ratio of 4:1 and covered with non-steel sheathings, the in-plane nominal shear strength can be determined via tests in accordance with ASTM E455, where the test results are calibrated in accordance with AISI S100 and the statistic values used in the calibration are those provided in AISI S240 Section B5.4.5.
(c) For cold-formed steel framed shear walls sheathed with steel sheet, a new Effective Strip Method is introduced to determine the nominal shear strength [resistance]. This method provides an alternative approach to determine the shear wall strength, especially for those that are outside the limitations of the tested systems. This method is also applicable to those shear walls used in seismic force-resisting systems.

Chapter C, Installation. This chapter provides installation requirements for structural members and connections in the structural framing systems included in Chapter B.

Chapter D, Quality Control and Quality Assurance. This newly developed chapter provides minimum requirements of quality control and quality assurance for material control and installation for cold-formed steel light-frame construction. In this chapter, the quality control program, provided by the component manufacturers and installers, is to ensure that the work is in accordance with AISI S240 and the construction documents; and the quality assurance program is provided by others, as required by authority having jurisdiction, the applicable building code, the owner, or the registered design professional.

Chapter E, Trusses. This chapter contains design, manufacturing quality criteria and installation requirements for cold-formed steel trusses, similar to those previously included in AISI S214.

Chapter F, Testing. This chapter lists applicable AISI test standards for cold-formed steel framing members, connections, and systems; and points to Appendix 2 for truss assembly and component tests.

Appendix 1, Continuously Braced Design for Distortional Buckling Resistance. This appendix can be used to determine the rotational stiffness of structural sheathing provided to framing members.

Appendix 2, Test Methods for Truss Components and Assemblies. The truss component structural performance load test and full-scale truss confirmatory test methods, previously included in AISI S214, are provided in this appendix.

2. **AISI S400-15, North American Standard for Seismic Design of Cold-Formed Steel Structural Systems**

AISI S400 was developed based on the previously published standards AISI S213 and AISI S110. This first edition brings cold-formed steel seismic design into a single standard, clarifies and adds consistency to the design requirements of cold-formed steel seismic force-resisting systems, and accommodates the growth of future systems. This standard includes the following chapters:

Chapter A, Scope and Applicability. This standard is applicable for the design and construction of seismic force-resisting systems including cold-formed steel members and connections and other structural components and diaphragms used in buildings and other structures. This standard should be used in conjunction with AISI S100 [CSA S136], AISI S240, and the applicable building code. The standard should be followed except in the following cases:

(a) For the US and Mexico: Seismic Design Category (SDC) is A; or SDC is B or C, and the seismic response modification coefficient, R, equals 3.

(b) For Canada: Seismic force modification factors, R_dR_o is less than 1.56, or the design spectral response acceleration S(0.2) is less than or equal to 0.12.

Chapter A also introduces the modification coefficients, such as R_y and R_t, for determining the expected material properties that are needed in seismic design.

Chapter B, General Design Requirements. This chapter outlines the basic seismic design requirements: The available strength [factored resistance] of the designated seismic force-resisting system shall be greater than or equal to the required strength [effects of factored loads] determined from the applicable load combinations. To ensure the performance of the designated seismic force-resisting system, other structural members and connections in the lateral force-resisting system that are not part of the designated energy-dissipating mechanism need to be designed for the expected strength [probable resistance] of the seismic force-resisting system but do not need to exceed the seismic load effects determined in accordance with the applicable building code, where the seismic load effects include overstrength (Ω_o) for the U.S. and Mexico, and seismic modification factors (R_dR_o=1.0) for Canada.

Detailed design information is provided in Chapter E for seismic force-resisting systems, and Chapter F for diaphragms.

Chapter C, Analysis. This chapter prescribes that the structural analysis should be done in accordance with the applicable building code and AISI S100. The chapter is intended to accommodate future development.

Chapter D, General Member and Connection Design Requirements. This chapter references Chapters E and F for member and connection design, and is intended to accommodate future development.

Chapter E, Seismic Force-Resisting Systems. In this chapter, design provisions for the following seismic force-resisting systems are provided, which were also included in AISI S213 and S110:

(a) Cold-formed steel light frame shear walls sheathed with wood structural panels
(b) Cold-formed steel light frame shear walls with steel sheet sheathing
(c) Cold-formed steel light frame strap-braced wall systems
(d) Cold-formed steel special bolted moment frames
(e) Cold-formed steel light frame shear walls with wood-based structural sheathing on one side and gypsum board panel sheathing on the other side (applicable in Canada only)

(f) Cold-formed light frame shear wall with gypsum board or fiberboard panel sheathing (applicable in the U.S. and Mexico only)

(g) Conventional construction of cold-formed steel light frame strap braced wall systems (applicable in Canada only)

In addition to providing the system limitations in each of the above listed systems, nominal strengths [resistances] and available strengths [factored resistance] are provided as in the previously published standards. In AISI S400, the designated energy-dissipating mechanism for each system is clearly identified, and the provisions are provided to determine the expected strength [probable resistance] of the designated energy-dissipating mechanism. The expected strength [probable resistance], capped by the seismic load effects including overstrength, is used to design other components in the seismic force-resisting system that are not part of the energy dissipating mechanism, and those components in the lateral force-resisting systems to transfer the seismic force to the seismic force-resisting systems.

Chapter F, Diaphragms. Acting to collect and distribute seismic forces to the seismic force-resisting systems, diaphragms should be designed to resist the forces specified by the applicable building code. The diaphragm stiffness needs to be taken into consideration in determining the required strengths of the seismic force-resisting system and the diaphragm itself, as the stiffness directly affects the force distribution. The standard currently provides the design provisions for cold-formed steel framed diaphragms sheathed with wood structural panels. It may be extended to include other diaphragm systems in the future.

Chapter G, Quality Control and Quality Assurance. The cold-formed steel light frame seismic force-resisting systems follow the provisions provided in AISI S240 Chapter D. For the special bolted moment frames, the QC and QA requirements are provided in Section G4.

Chapter H, Use of Substitute Components and Connections in Seismic Force-Resisting Systems. This chapter permits the substitution of components or connections in any of the seismic force-resisting systems specified in Chapter E as long as they follow the applicable building code requirements and are approved by the authority having jurisdiction.

Appendix 1, Seismic Force Modification Factors and Limitations in Canada. This appendix, which is applicable to Canada, contains design coefficients, system limitations and design parameters for seismic force-resisting systems. These provided values should only be used when neither applicable building code nor NBCC contains such values.

3. AISI S220-15, North American Standard for Cold-Formed Steel Framing—Nonstructural Members.

With the consolidation of AISI framing standards, this standard was revised and updated accordingly. The additions in this edition include:

(a) Addition of manufacturing tolerances for flange width and stiffening lip length of nonstructural members.
(b) Addition of screw penetration requirements and screw penetration performance test procedures (in Appendix 1).
(c) Reference to AISI newly developed test standards AISI S915 and AISI S916.

4. AISI S230-15, Standard for Cold-Formed Steel Framing—Prescriptive Method for One- and Two-Family Dwellings.

This standard was updated to bring its provisions into full compliance with the 2015 edition of the *International Residential Code*, ASCE 7-10 and its supplements, and the latest referenced documents. Provisions are added for larger openings in floors, ceilings, and roofs. To reduce complexity and volume of the provisions, following changes were made to the design tables:

(1) Eliminate provisions for 85 MPH wind exposure B wind speed.
(2) Tabulate solutions for just one material grade per thickness.
(3) Eliminate multi-span floor joist and ceiling joist tables.
(4) Eliminate tables for ceiling joists with bearing stiffeners.

5. AISI S310-16, North American Standard for the Design of Profiled Steel Diaphragm Panels

The first edition of this standard was published in 2013. A detailed review was provided in reference (11). The standard was updated to accommodate the reorganization of AISI S100-16. In addition, the safety and resistance factors for diaphragms were recalibrated based on an expanded database of full-scale diaphragm tests and the calibration method presented in AISI S310.

6. AISI S100-16, North American Specification for the Design of Cold-Formed Steel Structural Members

AISI S100-16 was reorganized to be parallel with ANSI/AISC 360 in format. The Direct Strength Method was incorporated into the main body of the Specification, which enables engineers to design members with unconventional cross–sections. To help users get familiar with the new content layout, a section numbering comparison between AISI S100-12 and AISI S100-16 is provided. The reorganized AISI S100-16 includes the following chapters:

Chapter A, Scope, Applicability, and Definitions. This chapter outlines the scope and applicability of the Specification: cold-formed steel structural members can be designed using AISI S100-16 through the design provisions provided in the specification (excluding those in Chapter K). If the composition or configuration is beyond those design provisions, the member strength can be determined by tests, by rational engineering analysis with confirmatory tests, or by rational engineering analysis with the following safety and resistance factors:

For members, Ω=2.00 (ASD); ϕ=0.80 (LRFD) or 0.75 (LSD)

For connections, Ω=3.00 (ASD); ϕ=0.55 (LRFD) or 0.50 (LSD).

Chapter B, Design Requirements. This chapter lists the essential design requirements: design for strength, structural members, connections, stability, structural assemblies and systems, serviceability, ponding, fatigue, and corrosion effects. The Specification also points to the appropriate chapters or sections for the design provisions. In addition, the application limitations for the Effective Width Method and the Direct Strength Method are provided, and these limitations are consolidated and greatly simplified.

Chapter C, Design for Stability. This chapter includes design provisions for considering structural system stability, and member stability. In this edition, the AISC Direct Analysis Method is adopted. Specifically, three approaches can be used for structural stability analysis:

(1) Rigorous second-order elastic analysis (including both P-Δ and P-δ effects) considering initial imperfections and adjustment of stiffness.

(2) First-order analysis considering initial imperfections and adjustment of stiffness, and both P-Δ and P-δ effects being considered using multipliers B1 and B2 (see Specification Equations C1.2.1.1-1 and C1.2.1.1-2). This method is limited to

structures that support gravity loads primarily through nominally vertical columns, walls or frames.

(3) Effective width method to adjust the P-Δ and P-δ effects by applying the effective length factors to members. This method is limited to structures that (1) support gravity loads primarily through nominally vertical columns, walls or frames; and (2) the maximum second-order drift does not exceed 1.5 times the maximum first order drift.

Chapter D, Members in Tension. This chapter includes tension member design provisions similar to those in the previous Specification edition.

Chapter E, Members in Compression. The column member design provisions consider the following possible failure modes: yielding and global buckling, local buckling interacting with yielding and global buckling, and distortional buckling. Both the Effective Width Method (EWM) and the Direct Strength Method (DSM) can be used for the design. For members with holes, comprehensive design provisions are provided with the DSM approach.

Chapter F, Members in Flexure. Similar to the column member design, the flexural member design also considers yielding and global buckling, local buckling interacting with yielding and global buckling, and distortional buckling. For flexural members, provisions are provided to determine the inelastic reserve capacities when members are subject to local, global or distortional buckling. The comprehensive design provisions for flexural members with holes are also provided with the DSM approach.

Chapter G, Members in Shear and Web Crippling. This chapter includes design provisions for determining the shear strengths of members with or without holes, shear strengths of members with or without web stiffeners, and web crippling strengths.

Chapter H, Members Under Combined Forces. This chapter includes the following interaction checks for members subjected to combined forces:

(1) Combined tensile axial load and bending; and combined compressive axial load and bending
(2) Combined bending and shear
(3) Combined bending and web crippling
(4) Combined bending and torsional loading

In this edition, the interaction equations for ASD, LRFD and LSD are unified wherever possible.

Chapter I, Assemblies and Systems. This chapter contains the design provisions included in Chapter D of the previous Specification editions. The following changes and additions are provided in this edition:

(1) For floor, roof or wall steel diaphragm construction, three AISI standards are referenced for different applications. For diaphragms and wall diaphragms constructed with profiled steel panels and decks, AISI S310 should be applied, and the safety and resistance factors for this type of diaphragm systems have been moved to AISI S310. AISI S240 should be used for diaphragms constructed with wood structural panels, shear walls covered with flat steel sheets, wood structural panels, gypsum boards or fiberboard panels, or strap braced cold-formed steel stud walls. AISI S400 should be followed for additional seismic design requirements.

(2) For cold-formed steel light frame construction and special bolted moment frame systems, the new AISI S240 and AISI S400 standards are referenced.

(3) For metal roof and wall systems, the compressive and flexural strengths of members covered with metal roof and wall panels can be determined analytically through the DSM approach where the buckling forces or moments should be determined including lateral, rotational, and composite stiffness provided by the metal deck or sheathing; bridging and bracing; and span continuity. The added provisions would enable engineers to design systems that may be outside the limitations of the empirical equations.

(4) For steel rack system design, ANSI MH16.1 (12) is referenced.

Chapter J, Connections and Joints. This chapter contains all the design provisions included in Chapter E of the previous Specification editions. The tension rupture provisions for a single bolt, or a single row having multiple bolts perpendicular to the force, are revised. The revised provisions contain a single shear lag reduction factor for all flat sheet bolted connections not having staggered hole patterns. In addition, the following design information is provided for cold-formed steel connecting other materials:

(1) Pull-out strength in shear for power-actuated fasteners connecting CFS track to concrete is added to Specification Section J7.2.

(2) Design references for cold-formed steel connecting to hot-rolled steel, aluminum, concrete, masonry, wood, and plywood are added to Commentary Section J7.

These design provisions and references are deemed proper for determining connection strengths when the strength is controlled by the other materials.

Chapter K, Strength for Special Cases. This chapter includes the complete list of AISI test standards, and the provisions to determine the structural performance (strengths) via tests, or via rational engineering analysis with confirmatory tests. In this edition, the Statistical Data for the Determination of Resistance Factor have been consolidated and greatly simplified. For diaphragm formed by profiled steel panels, the tests should be in accordance with AISI S310.

Chapter L, Design for Serviceability. This chapter includes the provisions for determining the moment of inertias used in serviceability calculations. The flange curling checks are included in this chapter. A rational approach is introduced in the Commentary when DSM is used.

Chapter M, Design for Fatigue. This chapter contains the fatigue design provisions similar to those in the previous Specification edition.

Appendix 1, Effective Width of Elements. This appendix contains all the provisions for determining the effective widths under different edge conditions and stress distributions, which were included in Chapter B of the previous Specification edition.

Appendix 2, Elastic Buckling Analysis of Members. This appendix provides information and references needed to determine the member buckling stresses or stress resultants with either numerical or analytical approach. These buckling stresses or resultants are used throughout Chapters C to H.

Appendix A, Provisions Applicable to the United States and Mexico. This appendix includes the provisions that are applicable to the Unites States and Mexico only. In this edition, country specific provisions are consolidated or eliminated wherever possible.

Appendix B, Provisions Applicable to Canada. This appendix includes the provisions that are applicable to Canada only.

7. **AISI S915-15, Test Standard for Through-the-Web Punchout Cold-Formed Steel Wall Stud Bridging Connectors.**

This test method is to provide test setup and methodology to determine the strength and stiffness of through-the-web punchout bracing (as shown in figure 1). This type of bracing is used in light frame construction to provide wall studs lateral and/or torsional restraints.

8. **AISI S916-15, Test Standard for Cold-Formed Steel Framing—Nonstructural Interior Partition Walls With Gypsum Board.**

This is a performance test standard for determining the strength and stiffness of nonstructural interior partition wall assemblies subjected to uniform static nominal pressure loads up to 15 pounds per square foot (0.72 kPa). The assembly is framed with cold-formed steel nonstructural members, and sheathed on one or both sides with gypsum board panel products.

9. Future Developments and Technology Transfer.

To continue the advancement of cold-formed steel design and construction, two standard development initiatives are proposed. For cold-formed steel framing design, the AISI Committee on Framing Standards will focus on improving the framing standards to enhance the design for mid-rise construction. For general cold-formed steel design, the Committee on Specifications is working towards developing analysis-based design, an approach intended to realistically model a structural system such that the design criteria (failure modes), will be taken into direct consideration through structural analysis. Such analysis would consider connection deformation, cross-section deformations, interactions of members and attachments, as well as system effects. The analysis-based design would provide engineers the flexibility to model/design a structural system from a preliminary to a comprehensive design.

To help the design community better understand AISI developed standards, the AISI Education Committee continues developing and updating technical design guides and design manuals. AISI D110, *Cold-Formed Steel Framing Design Guide* (13), which was updated based on AISI S240-15 and AISI S100-12 and published in April 2016, provides valuable design information, and practical framing design examples. AISI D100, *Cold-Formed Steel Design Manual* (14), will be updated based on the new edition of AISI standards. Most of the AISI standards can be downloaded for free from our website www.aisistandards.org.

References

1. AISI S200-12, *North American Standard for Cold-Formed Steel Framing-General Provisions*, 2012 Edition.
2. AISI S210-07 (2012), *North American Standard for Cold-Formed Steel Framing–Floor and Roof System Design*, 2007 Edition (Reaffirmed 2012).
3. AISI S211-07(2012), *North American Standard for Cold-Formed Steel Framing–Wall Stud Design*, 2007 Edition (Reaffirmed 2012).
4. AISI S212-07(2012), *North American Standard for Cold-Formed Steel Framing–Header Design*, 2007 Edition (Reaffirmed 2012).
5. AISI S213-07w/S1-09(2012), *North American Standard for Cold-Formed Steel Framing–Lateral Design* 2007 Edition with 2009 Supplement (Reaffirmed 2012).
6. AISI S214-12, *North American Standard for Cold-Formed Steel Framing–Truss Design*, 2012 Edition.
7. AISI S110-07 w/S1-09(2012), *Standard for Seismic Design of Cold-Formed Steel Structural Systems – Special Bolted Moment Frames*, 2007 Edition. with 2009 Supplement (Reaffirmed 2012).
8. ANSI/AISC 360-10, *Specification for Structural Steel Buildings*, 2012 Edition.
9. Schafer, B.W., H. Chen, B.E. Manley and J.W. Larson (2015), Enabling Cold-Formed Steel System Design Through New AISI Standards, *ASCE Proceeding Structures Congress 2015*.
10. AISI S100-12, *North American Specification for the Design of Cold-Formed Steel Structural Members*, 2012 Edition.
11. Mattingly, J and H. Chen (2014), AISI Newly Developed Standard AISI S310-13, North American Standard for the Design of Profiled Steel Diaphragm Panels, *Proceeding of the Twenty-Second International Specialty Conference on Cold-Formed Steel Structures*, Missouri University of Science and Technology, Rolla, MO, 2014.
12. ANSI MH16.1-12, *Specification for the Design, Testing and Utilization of Industrial Steel Storage Racks*, 2012.
13. AISI D110-16, *Cold-Formed Steel Framing Design Guide*.
14. AISI D100-13, *Cold-Formed Steel Design Manual*.

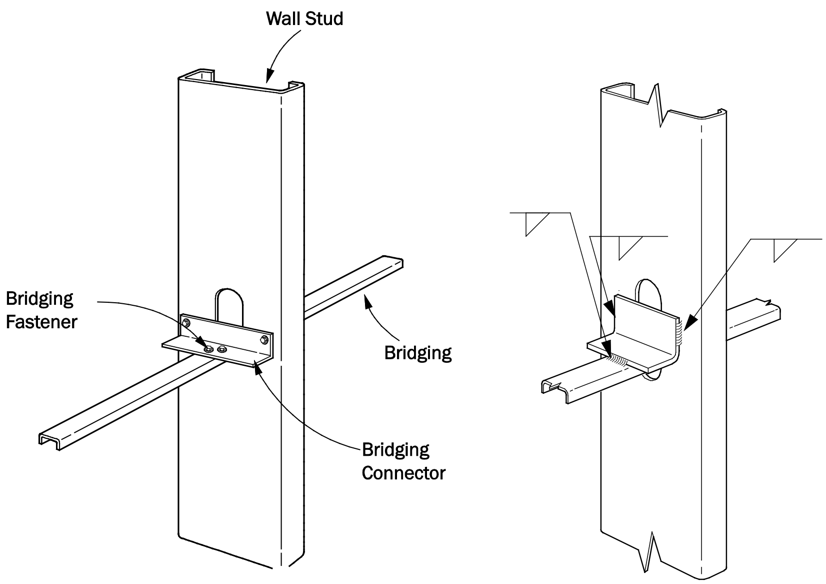

Figure 1 – Examples of Bridging Connector Assemblies