Enabling cold-formed steel system design through new AISI standards

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ABSTRACT

The objective of this paper is to introduce several new and updated AISI standards for cold-formed steel structural design and explain how these standards provide an evolution for cold-formed steel towards the design of systems instead of isolated members and connections. Cold-formed steel members are used in a wide variety of applications and the historical approach of the AISI standards was primarily to support the design of individual members and steel-to-steel connections. However, as the use of cold-formed steel has expanded and matured it is now possible in several cases to reliably define cold-formed steel systems that are in common use. To support these systems: cold-formed steel framing, metal building secondary systems, steel diaphragm systems, etc. AISI standards now provide system specific design specifications and test standards. The evolution of these standards and the latest versions are explained herein. The focus of the discussion is on why the standards are provided, and how they aim to enable the cold-formed steel engineer, rather than on the specifics of each new edition of the standard. The base standard for all the system specific efforts: AISI S100 is also being reorganized and updated to accommodate new research and this new evolution in cold-formed steel system design. Significant work remains to fully develop cold-formed steel system design and evolve it further towards performance-based standards, but the new suite of AISI standards provide a robust foundation for this effort.

1. INTRODUCTION

Cold-formed steel structures enjoy a potential for high efficiency by utilizing minimal material and smartly configuring the structural members to resist loads. However, efficiency of the individual member is only one small portion. The American Iron and Steel Institute (AISI), through its standards development process, is working to enable engineers to utilize and understand the much broader efficiencies available through the consideration of cold-formed steel structural systems. Table 1 provides current and forthcoming AISI standards mapped against the major cold-formed steel structural applications and broken down by the level of design (member, sub-system, system) considered. Significant effort has been expended in recent years to provide a more coherent and useful set of standards to enable cold-formed steel design.

Table 1 AISI Cold-Formed Steel Structural Standards Mapped Against Applications

	Cold-Formed Steel Structural Application			
Design Level	**Generic** (isolated member, and application)	**Framing** (studs, tracks, joists, repetitive framing, …)	**Metal Buildings** (secondary, … purlins, girts, steel sheet diaphragms)	**Racks** (down-aisle, cross-aisle, etc., beam to upright)
System or Sub-System	N/A	AISI S240-15 (framing) AISI S400-15 (seismic) AISI S220-11 (non-structural)	AISI S100-16 (Chapter I)	(MH16.1-2012[1])
Member or steel connection	AISI S100-16	AISI S100-16	AISI S100-16	AISI S100-16
Test-based design	AISI S9XX[2]	AISI S9XX[2]	AISI S9XX[2]	(MH16.1-2012[1])

[1] maintained and produced by the Rack Manufacturers Institute
[2] suite of AISI test standards, other non-AISI test standards are also referenced/used in AISI standards

Repetitive framing utilizing cold-formed steel members has seen the greatest attention in the development of standards for cold-formed steel systems. In 1997, dedicated work on standards for cold-formed steel structural framing began, and, this year this effort will culminate in a single structural standard – AISI S240 (2015). This standard provides design methods for cold-formed steel sub-systems: roofs, floors, walls, lateral force resisting systems, trusses, etc. Work is underway to utilize the latest research on these sub-systems to benefit design, and also to amalgamate the subsystems into the full building. For seismic design, system design plays a critical role. To this end, AISI S400 (2015) is being completed to bring together all current knowledge on cold-formed steel seismic design into a single document under a consistent capacity-based design philosophy. Significant work remains to develop full system-level seismic design, but the philosophies in AISI S400 will provide the framework for accomplishing this effort, and current research indicates large potential benefits in this regard. Finally, recognizing that non-structural applications of cold-formed steel (e.g. interior partition walls) are small systems in their own right, the recently developed AISI S220 (2011) standard provides requirements for non-structural system design.

Application of cold-formed steel systems extends far beyond framing. The foundation for all cold-formed steel design begins with AISI S100 (2016). The next edition of S100, which is already in process and will be published in 2016, will be significantly updated, both in format and content. In format, AISI S100 will parallel AISC 360, Specification for Structural Steel Buildings. A significant feature of this change will be the integration of second-order system analysis for structural system stability. In addition, the Direct Strength Method will be integrated within the body of AISI S100 allowing unparalleled flexibility in the use of different cold-formed steel cross-sections. AISI S100 will still maintain key provisions for metal roofing systems and other applications outside of framing. Given the long term desire to perform meaningful system level design AISI S100 is now working to expand its application to provide guidance on modeling stiffness of cold-formed steel systems necessary for accurate design accounting for the interaction of cold-formed steel members, connections, sub-systems, and complete systems.

This paper provides a summary of these advances in the AISI standards within the context of enabling system design for cold-formed steel structures.

2. COLD-FORMED STEEL FRAMING SYSTEMS

Specifications for cold-formed steel framing systems have seen the most significant evolution for any cold-formed steel application in the last 15 years. Table 2 shows how the current standards for framing, covering structural systems (AISI S240-15), non-structural systems (AISI S220-11), and seismic force resisting systems (AISI S400-15) evolved from a very large suite of individual standards. Specifically, in 2016, AISI standards: S110, S200, S210, S211, S212, S213 and S214 were consolidated into AISI S240-15 and AISI S400-15. The current suite of standards provides a comprehensive foundation for developing full systems-based standards for cold-formed steel framing.

Table 2 Evolution of AISI Framing Standards 2001-2016

<table>
<tr><th>Year</th><th colspan="2">Nonstructural Systems</th><th colspan="7">Structural Systems</th><th colspan="2">Seismic Force Resisting Systems</th></tr>
<tr><td>2016</td><td colspan="2" rowspan="2">S220</td><td colspan="7">S240</td><td colspan="2">S400</td></tr>
<tr><td>2012</td><td>S200</td><td rowspan="2">S210</td><td rowspan="2">S211</td><td rowspan="2">S212</td><td rowspan="4">n/a</td><td rowspan="2">S214</td><td colspan="2" rowspan="2">S213</td><td rowspan="2">S110</td></tr>
<tr><td>2007</td><td rowspan="3">n/a</td><td colspan="2">S200</td></tr>
<tr><td>2004</td><td colspan="2" rowspan="2">GP</td><td rowspan="2">n/a</td><td>WSD</td><td rowspan="2">Header</td><td rowspan="2">Truss</td><td colspan="2">Lateral</td><td rowspan="2">n/a</td></tr>
<tr><td>2001</td><td>n/a</td><td colspan="2">n/a</td></tr>
<tr><td rowspan="2"></td><td rowspan="2">Drywall Framing (Walls and Ceilings)</td><td colspan="2" rowspan="2">General Provisions</td><td rowspan="2">Floor and Roof Systems</td><td rowspan="2">Wall Studs</td><td rowspan="2">Headers</td><td rowspan="2">Quality Control and Quality Assurance</td><td rowspan="2">Trusses</td><td colspan="2">Shear Walls, Strap Braced Walls, and Diaphragms</td><td>Special Bolted Moment Frames</td></tr>
<tr><td>Ordinary Systems</td><td colspan="2">Special Seismic Systems</td></tr>
</table>

2.1. Structural (AISI S240-15)

Load bearing cold-formed steel structural systems, for example see Figure 1, are supported by the AISI S240-15 standard. This standard covers complete gravity and lateral systems, and provides design guidance on sub-systems such as headers, shear walls, etc. The AISI S240 standard essentially provides two levels of design guidance. The simplest, level 1, is a roadmap to the application of AISI S100 and typically provides little system benefit. For some cases, level 2 is provided, where additional new rules that are specific to cold-formed steel framing are detailed. The standard is organized such that when developed the higher, level 2, guidance can be provided in all situations.

(a) mid-rise apartments framed from CFS (b) CFS shear wall installation

Figure 1 Example of Cold-Formed Steel Framing Construction
(photos courtesy of ClarkDietrich Building Systems)

Consider for example the simple case of designing a header (CFS members above an opening). Back-to-back headers are treated simply by level 1, i.e. referencing the all-steel member provisions of AISI S100. Figure 2a provides a simple header detail in actual construction. The impact of end details on the header and how it is framed into the studs, the impact of ledgers and other large structural members framing into the same studs, and/or the impact of non-structural finishes, etc. on the header composite strength are all ignored. Even in simple systems the actual solution may vary significantly from the engineering idealization and in the future S240 will provide guidance for this. Specific testing has been conducted on box headers. These tests showed that the web crippling capacity of these members benefited from their connection to the track. Thus, AISI S240 provides additional guidance for this benefit, specific to framing design.

(a) typical header, ledger, and joist (b) interior wall and joists during sheathing

Figure 2 Example Cold-Formed Steel Framing Details
(photos form CFS-NEES project, photo credit Kara Peterman)

In addition to providing system benefits, or a roadmap to the application of AISI S100 member design, in some situations the system must be known for a proper design to be completed. For example, in cold-formed steel framed trusses the eccentricities that develop in C-section chords and webs in a back-to-back connection configurations must be considered and AISI S240 provides specific guidance so this design may be completed correctly.

In the preceding examples, the assemblies are all steel. However, it is known that sheathing offers significant benefits in wall, roof, and floor systems. For example, Figure 2b shows a typical interior framing situation. Sheathing will still be applied to the bottom flange of the joists before completing. The gravity design of all walls in this example ignored any beneficial impact of sheathing and used only all-steel bridging in the design. AISI S240 provides basic guidance for consideration of the beneficial impact of sheathing. For example, the beneficial rotational restraint from sheathing to restrict distortional buckling can be considered. In addition, prescriptive criteria are provided for floor systems so that they may ignore lateral-torsional buckling. Under development now, for the next edition of AISI S240, is a comprehensive approach that allows restraint provided from sheathing (e.g., OSB, gypsum board, plywood, etc.) to be considered, as decided by the engineer, for walls, floors, and roofs. This comprehensive sheathing-braced design methodology will allow engineers to fully assess the structural impact of sheathing on the strength of CFS systems. Today, AISI S240 (2015) already provides practical guidance and simplified methods where appropriate.

2.2. Seismic (AISI-S400-15)

Prior to 2013 AISI seismic standards included AISI S213 and S110. AISI S213, *North American Standard for Cold-Formed Steel Framing – Lateral Design*, addressed "the design and installation of cold-formed steel light-framed shear walls, diagonal strap bracing (that is part of a structural wall) and diaphragms to resist wind, seismic and other in-plane lateral loads." This standard included provisions for the U.S., Canada and Mexico. AISI S110, *Standard for Seismic Design of Cold-Formed Steel Structural Systems – Special Bolted Moment Frame*, applied to "the design and construction of cold-formed steel members and connections in seismic force resisting systems (SFRS) in buildings and other structures." As originally written, the standard applied in the U.S. only and included just one SFRS system – the CFS special bolted moment (CFS-SBMF) frame.

The requirements in each of these AISI standards encompassed the necessary detailing requirements for the specific SFRS; while the SFRS' seismic design parameters (SDP) – i.e. the response modification coefficient, R, Ω_o, the deflection amplification factor, C_d, and the structural height limits – are specified in either ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, for the U.S., or the *National Building Code (NBC) for Canada*. This dual path is relatively unique to seismic design and is necessary due to the heavy reliance on inelastic deformations at the maximum considered earthquake (MCE) load.

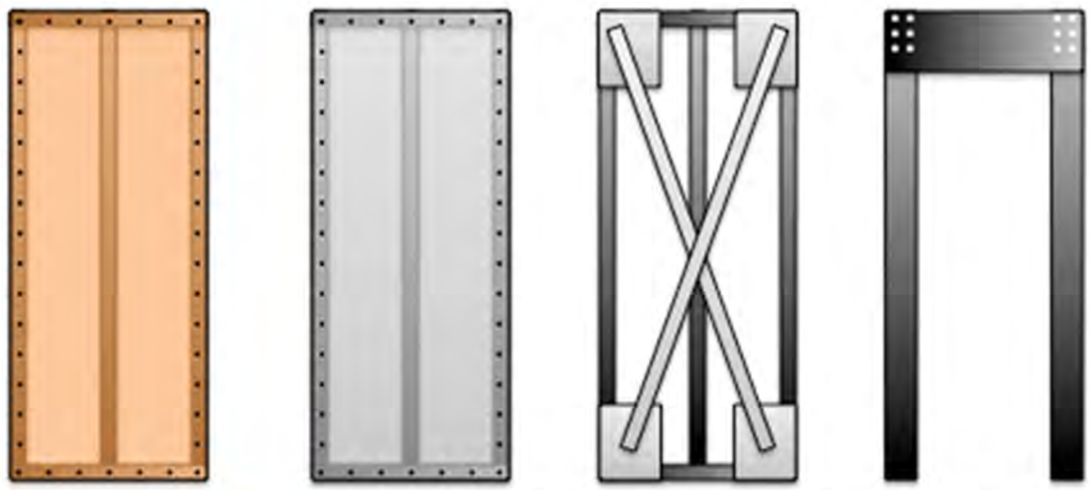
Significant changes to a SFRS' detailing requirements or SDPs must be coordinated between the involved documents and, in the U.S, often require review and approval by the membership of a third, independent body – the National Earthquake Hazard Reduction Program (NEHRP). This process lengthens and complicates the development of seismic design standards. In fact, in the U.S., the process to vet new seismic provisions can take upwards of eight years from start in the NHERP process, to incorporation into ASCE 7 and the relevant materials standards, to conclusion via adoption in the model building codes.

In 2013, the AISI Standards Council and the COFS Main Committee approved a Strategic Plan to consolidate the cold-formed steel framing standards into one ANSI standard, the new AISI S240. As part of that original plan, AISI S213 was to be incorporated into AISI S240 in its entirety. This would subject the contents formerly in AISI S213 and the contents formerly in AISI S200, S210, S211, S212 and S214 to a longer and more extensive approval process. Consequently, the AISI Standards Council thought it was worthwhile to stop and reconsider how this change would impact the development and dissemination of CFS seismic design provisions. Ultimately, the decision was made to develop a separate unified seismic design standard for both cold-formed steel (CFS) and cold-formed steel framing (CFSF), rather than subject the non-seismic provisions in AISI S240 to a lengthy adoption process and continue to maintain seismic design requirements in two separate standards – AISI S110 and AISI S240. In fact, the AISI Standard Council's vision was that AISI S110 could be expanded to the North American market, include all applicable SFRS that utilize CFS, and be renumbered as AISI S400. This approach would be similar to that taken by other material standard developing organizations. For instance, AISC currently maintains general structural steel requirements in AISC 360; while, provisions for structural steel SFRS are specified in AISC 341.

Focusing on high seismic design applications in one standard provides both internal and external benefits. Internally, it consolidates subcommittees, focuses expertise, and provides a platform for growth of new CFS SFRS. Externally, it allows for the necessary review by the NEHRP membership and coordination with ASCE 7 and NBC without holding up the development of non-seismic-related CFS and CFSF provisions. The scope of the new AISI S400 is "This *Standard* is applicable for the design and construction of *cold-formed steel structural members* and *connections* in *seismic force-resisting systems* and diaphragms in buildings and *other structures*."

The new AISI S400 now contains seismic design for CFS in one, standalone system specific standard. When new SFRS become available, they will be easily incorporated into the standard, since Chapter E is broken down into system specific requirements. Also, as diaphragm requirements receive further development in coming years, Chapter F will be able to be expanded to accommodate those material specific requirements.

AISI S400 brings all cold-formed steel seismic systems together in one standard, organizes all these systems around the shear capacity provided by the system, provides a consistent capacity-based design philosophy to all systems, including explicitly addressing the designated energy dissipating mechanism in each system. For example, the basic SFRS systems included are shown in Figure 3: (a) CFS-framed wall with a wood structural panel, (b) CFS-framed wall with steel sheet, (c) CFS-framed wall with steel straps, and (d) CFS special-bolted moment frame.



(a) wood panel (b) steel sheet (c) strap braced (d) bolted frame

Figure 3 Example Seismic Force Resisting Systems Provided in AISI S400

The base shear capacity for each system is provided through expressions or tables. For each system the designated energy dissipating mechanism is defined (e.g., bearing and deformation at the panel-to-stud connection in the system of Figure 3a). The detailing requirements necessary for achieving this mechanism are also defined (e.g. stud sizes, fastener sizes, hold down details, etc.). In addition, based on the expected strength of the designated energy dissipating mechanism, the remaining portions of the load path are capacity designed. For cases where the expected strength of the designated energy dissipating mechanism has not been studied in detail conventional overstrength (Ω_o) is employed, when better information is available it is utilized. The end result is a consistent seismic design philosophy that provides a clear basis for expansion to additional systems and improvements in analysis.

2.3. Non-structural (AISI S220-11)

From the standpoint of tonnage of steel, the most common cold-formed steel members are those used for non-structural applications, such as shown in Figure 4. Prior to 2011 AISI did not provide a separate standard for the design of such members; however, as their use has grown along with provisions from applicable building codes, it became necessary to provide a consistent methodology for the design of non-structural members. Although the required loads are generally set by applicable building codes AISI S220 addresses how either AISI S100 or testing may be used to complete the design of non-structural members. Of particular note, AISI S220 recognizes that safety for a member is the convolution of the probability of failure with the consequence of that failure. Since the consequence of failure is less for non-structural members AISI S220 provides reduced reliability (i.e., a lower β) for non-structural members than structural members. This lower β is employed for both prescriptive design and for test-based design via the provisions of S220.

(a) infill curtain wall

(b) interior wall framing

Figure 4 Examples of Non-structural Cold-Formed Steel Applications
(photo credit Don Allen)

It is well established that non-structural systems contribute considerably to overall building performance. The existing S240 standard for framing is beginning to consider this influence in special situations, but it is clear that in the long-term to reliably predict building response for performance-based design standards the role of non-structural systems will have to be explicitly considered. Having an engineering basis for non-structural systems is thus critical, and S220 provides the beginning for this basis.

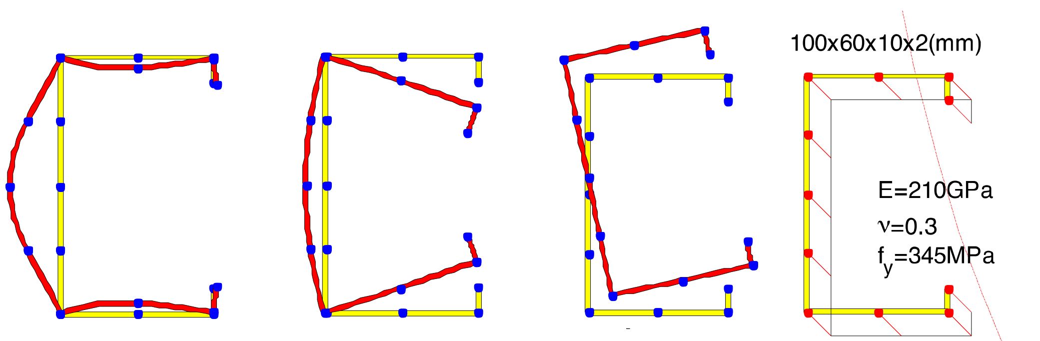
3. AISI S100-16 THE NEW RESOURCE FOR FUNDAMENTAL CFS DESIGN

As Table 1 makes clear, limit states based strength design of cold-formed steel members and steel connections are provided in AISI S100. AISI S100 is the foundational design document for all cold-formed steel structural design. In fact AISI S100 is a North American document and is the foundational design document for Canada, Mexico, and the United States. Although specific applications are addressed at least partially; the focus of AISI S100 is on individual member and connection design. AISI S100 provides a design method for nearly any open cold-formed steel member that can be formed and for nearly any type of steel-to-steel connection that has been used in the past. This section describes some of the unique features of AISI S100 when compared with other material specifications, details the new format adopted in 2016, and discusses new and existing design approaches as related to system design

3.1. Unique design philosophies in AISI-S100

AISI S100-16, directly in Chapter A, recognizes that many situations may exist that are outside the scope of the explicit standard provisions. In such a situation (due to a unique member, connection detail, application, etc.) AISI S100 dictates three possible courses of action: (a) strength by test, (b) strength by rational engineering analysis with confirmatory testing, or (c) strength by rational engineering analysis alone. For (a) and (b) a comprehensive method is provided so that the engineer can develop reliable safety and/or resistance factors for their design. In essence AISI S100 dictates that if one can calculate they must, but if one cannot calculate per the Specification they may engineer a solution and AISI S100 will help them make that solution a reliable one. For engineers looking to better understand system effects these test or rational engineering analysis based design methods provide additional avenues of exploration.

Cold-formed steel members are generally thin. As a result they potentially have multiple cross-section buckling modes, as shown in Figure 5, in addition to traditional member (global) buckling modes such as flexural buckling, or lateral-torsional buckling. A powerful feature of AISI S100 has always been the specification's ability to predict the strength of such members. Prior to 2004, the Effective Width Method was employed for handling the local, and in part, distortional buckling modes. In 2004, the Effective Width Method was joined by the Direct Strength Method. The Direct Strength Method uses cross-section elastic buckling solutions and has a very broad range of applicability to different cold-formed steel cross-sections. In 2016 these two methods have been placed side-by-side in the main body of AISI S100, allowing the engineer to readily choose which method best serves their design and to leverage past practice (i.e. the Effective Width Method) as they explore the new design spaces opened up by the Direct Strength Method. Utilizing an extension to the provisions of Chapter A, the Direct Strength Method provides a unique procedure for developing new cross-sections and performing limited confirmatory testing.



(a) local (b) distortional (c) global (d) loading and section

Figure 5 Buckling Modes of a Typical Cold-Formed Steel Cross-Section

3.2. A new format for AISI-S100-16

The first edition of the AISI Specification (now AISI S100) was developed in 1946. Since then, this document has been evolved, revised, and updated. With the development of construction technology, the application of cold-formed steel structural systems has increased and it has becomes evident that AISI S100 may need to evolve. Starting in 2012 the AISI Committee on Specifications began examination of a new format for the AISI S100 standard. The resulting standard was based largely on the strawman proposal provided in Table 3. A key feature of the proposal was an attempt to bring steel design closer together by provided cold-formed steel design in largely the same format as hot-rolled steel design, i.e., following the format of the AISC 360 standard where possible. As Table 3 indicates for AISC Chapters A-H, and J this was readily doable; however for AISC Chapters I, K-M and the Appendices some variation was required to fully incorporate the unique provisions for cold-formed steel. The committee adopted the new structure, after much discussion, to provide a familiar structure for steel design, and believing that the format provided a better foundation for incorporating system design and future developments.

Table 3 Strawman Mapping of AISI-S100-07 to new AISI-S100-16, used by Committee

AISI-S100-07	AISC-360-10	AISI-S100-XX STRAWMAN
A. General Provisions	A. General Provisions	A. General Provisions (→A)
B. Elements	B. Design Requirements	B. Design Requirements (→A)
	C. Design for Stability	C. Design for Stability
		C1. System (new B_1,B_2 + →App. 2)
C. Members		C2. Bracing (new + →D3)
C1. Properties		
C2. Tension	D. Design of Members for Tension	D. Members in Tension (→C2)
C3. Flexural Members	E. Design of Members for Compression	E. Members in Compression (→C4)
C4. Concentrically Loaded Compression Members	F. Design of Members for Flexure	F. Members in Flexure (→C3)
	G. Design of Members for Shear	G. Members in Shear & Web Cr. (→C3)
C5. Combined Axial Load and Bending	H. Design of Members for Combined Forces and Torsion	H. Members under Combined Forces (→C5,C3)
D. Structural Assemblies and Systems	I. Design of Composite Members	I. Assemblies and Systems
D1. Built-Up Sections		I1. Built-Up Sections (→D1)
D2. Mixed Systems		I2. Steel Deck Diaphragms (→D5)
D3. Lateral and Stability Bracing		I3. Mixed Material Assemblies (→D2)
D4. Cold-Formed Steel Light-Frame Construction		I4. Light Steel Framing (→D4)
		I5. Rack Systems (ref. RMI)
D5. Floor, Roof, or Wall Steel Diaphragm Construction		I6. Metal Building Secondary Systems (→D6)
D6. Metal Roof and Wall Systems		
E. Connections and Joints	J. Design of Connections	J. Connections and Joints (→E)
F. Tests for Special Cases	K. Design of HSS and Box Members Connections	K. Available Strength for Special Cases
G. Design of Cold-Formed Steel Structural Members for Cyclic Loading (Fatigue)		1.1 Rational Analysis (→A)
	L. Design for Serviceability	1.2 Test Standards (ref. only)
	M. Fabrication and Erection	1.3 Reliability via testing (→F)
	N. Quality Control and Quality Assurance	L. Design for Serviceability (I_{eff})
App. 1 Design of Cold-Formed Steel Structural Members Using the Direct Strength Method		M. Design for Fatigue (→G)
	App. 1 Design by Inelastic Analysis	
	App. 2 Design for Ponding	App. 1 Effective Width of Elements (→B)
App. 2 Second-order Analysis	App. 3 Design for Fatigue	App. 2 Elastic Buckling of Members (new)
	App. 4 Structural Design for Fire …	
App. A Provisions Applicable to the United States and Mexico	App. 5 Evaluation of Existing Structures	App. A Provisions Applicable to the United States and Mexico (→App. A)
	App. 6 Stability Bracing for Columns & Beams	
App. B Provisions Applicable to Canada	App. 7 Alt. Methods of Design for Stability	App. B. …Applicable to Canada (→App. B)
	App. 8 Approx. Second-Order Analysis	
Blue chapter/section numbers are reflected in third column in terms of their new location.	Grey sections of AISC are not covered or intended to be covered in AISI	→A indicates all or part of AISI-S100-07 would be in the new section.

In addition to the new layout paralleling AISC 360, AISI S100 also included the following major revisions: (1) the Direct Strength Method was moved into the main body of the standard and provided in a parallel fashion to the Effective Width Method; (2) all of the detailed provisions for effective width determination were moved in an appendix, similarly, most of the detailed analytical expressions for cross-section elastic buckling prediction were also moved into an appendix; (3) system stability design provisions that parallel the AISC Direct Analysis Method were adopted; (4) wherever possible unified design formulas for ASD (U.S.), LRFD (U.S. and Mexico), and LSD (Canada) were employed; (5) Country specific provisions were consolidated and eliminated wherever possible.

3.3. New system stability provisions in AISI S100-16

Chapter C of AISI S100-16, which essentially parallels Chapter C of AISC 360, is a major advancement for the AISI Specification. For the first time the AISI S100 Specification explicitly addresses P-Δ and P-δ amplifications. Prior to 2016, with the exception of Appendix 2, AISI S100 was silent on P-Δ amplification. In addition, the preamble to the new AISI S100-16 Chapter C makes it clear that stability determination for cold-formed steel structures should include all the same influences as hot-rolled steel structures (the two preambles are nearly the same); however, it is important that cold-formed steel members also consider "stiffness reductions due to cross-section deformations or local and distortional deformations."

AISI S100-16 Chapter C provides three methods for achieving the desired stability analysis and determining the required forces and moments on members (in the deformed shape as is necessary for stability analysis): (1) rigorous second-order elastic analysis, (2) amplified first-order elastic analysis, and (3) the effective length method. Method (1) is the most general and is primarily based on AISI S100-12 Appendix 2. The use of approaches (2) and (3) are subject to provided limitations – but provide an important bridge to past practice. In many cases, cold-formed steel specialty engineers may not have the necessary information for the full structure to complete a rigorous structural stability analysis and maintaining the traditional methods (i.e. effective length) is still necessary at this time.

3.4. Sub-system and systems in AISI-S100

Although AISI S100 is not itself a system specification it recognizes that cold-formed steel structural members are not designed in isolation. In particular AISI S100-16 Chapter I provides the necessary pointers to AISI standards and others, similar to Table 1, for system design. Specifically, I4 references AISI S240 for framing, and I5 references MH16.1 for racks. Metal buildings are handled differently since currently there is not a single specification to point towards. For floor, roof, or wall diaphragms designed from profiled steel sheeting, as is common in metal building systems, AISI 310-13 is referenced. For purlin and girt design that considers the benefit of steel sheeting I6.1 is provided. For standing seam roof systems I6.2 is provided. For anchorage of prulins and girts in metal building roofing systems I6.3 is provided. In effect I6 provides all available sub-system design criteria for metal building secondary systems.

4. ADDITIONAL AISI RESOURCES

A number of additional AISI resources support the design of cold-formed steel structural systems. For example, AISI provides a suite of 14 test standards AISI S901 – S914, that cover testing of individual connections and members up through complex systems such as purlins connected to standing seam roofs. In addition, AISI provides Design Guides (e.g. on cold-formed steel framing and steel stud brick veneer walls) and the AISI Design Manual (a complete resource to the use of AISI S100). A more extensive collection of practical technical guidance on the application of AISI Standards to cold-formed steel structural systems is provided by AISI affiliate: the Cold-Formed Steel Engineers Institute (CFSEI). CFSEI provides over 50 peer reviewed Technical Notes on cold-formed steel framing covering a wide variety of topics ranging from materials and fasteners to lateral systems design, and including important ancillary issues such as fire, acoustic, and thermal performance.

5. FUTURE EFFORTS

As the AISI Specification committees continue to advance the AISI Standards two major initiatives have been established for the current development cycles. For faming (AISI S240 in particular) the focus is on improving the standards to be more amenable to mid-rise framing. The original framing standards were largely developed with low-rise applications in mind, and in many cases guidance is not provided for demands and details common in mid-rise framing systems. For general cold-formed steel structures (AISI S100) the focus is to enable analysis-based design wherever possible. Given the extreme variety of potential systems and the complexity at the member level for cold-formed steel it is assumed that the evolution from members to systems will largely be enabled in the analysis domain. If models of cold-formed steel systems can correctly included connection deformations, cross-section deformations, and the true complexities of cold-formed steel structures then system-level tools and the related benefits can be pursued. Such a vision is also compatible with performance-based design goals, which also focus on system response. A special task group has been developed and is working on a roadmap to assist the committee in advancing this long term effort.

6. CONCLUSIONS

The standards supporting cold-formed steel structural design have been significantly consolidated, updated, and aligned with modern and future structural engineering needs. This paper provides structural engineers with an understanding of how the latest AISI standards apply and enable the design of complete cold-formed steel structural systems. The consolidated standards for cold-formed steel framing: AISI S240 (structural), AISI S400 (seismic), and AISI S220 (non-structural) are briefly detailed along with the foundational document for all cold-formed steel design: AISI S100. The goal of the improved standards is to enable system design and its benefits wherever possible and to provide engineers with tools that allow them to leverage the complete flexibility of designing cold-formed steel solutions. Current efforts are focused on improving the standards, developing additional provisions for mid-rise framing solutions, and expanding the situations where analysis may replace or supplement traditional prescriptive design.

7. REFERENCES

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