AISI STANDARD

North American Standard for Cold-Formed Steel Structural Framing

2015 Edition
DISCLAIMER

The material contained herein has been developed by the American Iron and Steel Institute (AISI) Committee on Framing Standards. The Committee has made a diligent effort to present accurate, reliable, and useful information on cold-formed steel framing design and installation. The Committee acknowledges and is grateful for the contributions of the numerous researchers, engineers, and others who have contributed to the body of knowledge on the subject. Specific references are included in the Commentary.

With anticipated improvements in understanding of the behavior of cold-formed steel framing and the continuing development of new technology, this material will become dated. It is anticipated that AISI will publish updates of this material as new information becomes available, but this cannot be guaranteed.

The materials set forth herein are for general purposes only. They are not a substitute for competent professional advice. Application of this information to a specific project should be reviewed by a design professional. Indeed, in many jurisdictions, such review is required by law. Anyone making use of the information set forth herein does so at their own risk and assumes any and all liability arising therefrom.

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This first edition of AISI S240, *North American Standard for Cold-Formed Steel Structural Framing*, is dedicated to John P. Matsen, P.E. John was a widely respected structural engineer for over three decades and founder and principal of Matsen Ford Design Associates. Throughout his career, he helped pioneer and expand the use of cold-formed steel framing in structural and nonstructural applications.

From the inception of the AISI Committee on Framing Standards in 1998, John was an active member. He served as chair of its High Wind Subcommittee from 1998 to 2001, enabling the AISI *Standard for Cold-Formed Steel Framing—Prescriptive Method for One- and Two-Family Dwellings* to be expanded in scope to address high wind areas. He actively engaged in the Committee’s numerous subcommittees and task groups, and was always an effective contributor.

John was also an active member of the Cold-Formed Steel Engineers Institute, helping to author and review technical notes, providing webinars, serving as a member of the Executive Committee, and leading as Chair of the Institute from 2009 to 2010. John was always willing to offer his expertise to help advance the profession.

The cold-formed steel industry gratefully acknowledges his many enduring contributions.
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PREFACE

The American Iron and Steel Institute (AISI) Committee on Framing Standards has developed AISI S240, *North American Standard for Cold-Formed Steel Structural Framing*, to address requirements for construction with cold-formed steel structural framing that are common to prescriptive and engineered design. This Standard is intended for adoption and use in the United States, Canada and Mexico.

This Standard integrated the following AISI Standards into one document:
- AISI S200-12, *North American Standard for Cold-Formed Steel Framing-General Provisions*
- AISI S210-07 (2012), *North American Standard for Cold-Formed Steel Framing—Floor and Roof System Design* (Reaffirmed 2012)
- AISI S212-07(2012), *North American Standard for Cold-Formed Steel Framing—Header Design* (Reaffirmed 2012)
- AISI S213-07w/S1-09(2012), *North American Standard for Cold-Formed Steel Framing—Lateral Design with Supplement 1* (Reaffirmed 2012)
- AISI S214-12, *North American Standard for Cold-Formed Steel Framing—Truss Design*

Consequently, AISI S240 will supersede all previous editions of the above-mentioned individual AISI Standards.

In 2015, AISI S400, *North American Standard for Seismic Design of Cold-Formed Steel Structural Systems*, was developed. Modifications were made to align the provisions of AISI S240 with AISI S400, as follows:
- The applicability of AISI S240 for seismic design was limited to applications when specific seismic detailing is not required.
- Definitions no longer needed in AISI S240 were removed and remaining definitions were revised, if needed, for consistency with AISI S400.
- Seismic-specific tables for nominal shear strength [resistance] were deleted.
- Seismic-specific safety factors and resistance factors were deleted.
- Other seismic-specific requirements were removed, as appropriate, and remaining requirements were generalized for applicability to wind, seismic or other lateral loads.

Also in this edition, a new Chapter F on testing was added to allow reference to applicable AISI 900-series test Standards. Methods for truss tests, formerly in Section E7, were moved to Appendix 2.

While not necessary, use of the more stringent requirements for structural members that are in this Standard for nonstructural members should be permitted, since these should demonstrate equivalent performance for the intended use to those specified in AISI S220, *North American Standard for Cold-Formed Steel Framing—Nonstructural Members*.

The Committee acknowledges and is grateful for the contributions of the numerous engineers, researchers, producers and others who have contributed to the body of knowledge on the subjects. The Committee wishes to also express its appreciation for the support of the Canadian Sheet Steel Building Institute.
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<td>Simpson Strong-Tie</td>
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<tr>
<td>Sutton Stephens</td>
<td>Pacific Northwest Engineering, Inc.</td>
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<tr>
<td>Lei Xu</td>
<td>University of Waterloo</td>
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<tr>
<td>Cheng Yu</td>
<td>University of North Texas</td>
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<td>Rahim Zadeh</td>
<td>Steel Stud Manufacturers Association</td>
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LATERAL DESIGN SUBCOMMITTEE

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Helen Chen, Secretary  American Iron and Steel Institute
Don Allen  Super Stud Building Products
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Tom Sputo Steel Deck Institute
Steven Walker Light Gauge Steel Engineering Group, Inc.
Rahim Zadeh Steel Stud Manufacturers Association
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<td>Kirk Grundahl</td>
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NORTH AMERICAN STANDARD
FOR COLD-FORMED STEEL STRUCTURAL FRAMING

A. GENERAL

A1 Scope

A1.1 This Standard applies to the design and installation of structural members and connections utilized in cold-formed steel light-frame construction applications.

A1.2 The design and installation of cold-formed steel framing for the following systems shall be in accordance with AISI S100 [CSA S136] and this Standard:
   (a) floor and roof systems in buildings,
   (b) structural walls in buildings,
   (c) shear walls, strap braced walls and diaphragms to resist in-plane lateral loads, and
   (d) trusses for load-carrying purposes in buildings.

A1.3 Cold-formed steel structural members and connections in seismic force-resisting systems and diaphragms shall be designed in accordance with the additional provisions of AISI S400 in the following cases:
   (a) In the U.S. and Mexico, in seismic design categories (SDC) D, E, or F, or wherever the seismic response modification coefficient, R, used to determine the seismic design forces is taken other than 3.
   (b) In Canada, where the design spectral response acceleration S(0.2) as specified in the NBCC is greater than 0.12 and the seismic force modification factors, R_dR_o, used to determine the seismic design forces, are taken as greater than or equal to 1.56.

A1.4 Cold-formed steel framing for floor and roof systems, and structural walls, as listed in items A1.2(a) and A1.2(b), are also permitted to be designed solely in accordance with AISI S100 [CSA S136].

A1.5 Elements not specifically addressed by this Standard shall be constructed in accordance with applicable building code requirements.

A1.6 This Standard does not preclude the use of other materials, assemblies, structures or designs not meeting the criteria herein, when the other materials, assemblies, structures or designs demonstrate equivalent performance for the intended use to those specified in this Standard. Where there is a conflict between this Standard and other reference documents, the requirements contained within this Standard shall govern.

A1.7 This Standard includes Chapters A through F and Appendices 1 and 2 in their entirety.

A2 Definitions

A2.1 Terms

Where the following terms appear in this Standard in italics, they shall have the meaning herein indicated. Terms included in square brackets shall be specific to LSD terminology. Where a country is indicated in square brackets following the definition, the definition shall apply only in the country indicated. Terms not defined in Section A2.1 shall have the ordinary accepted meaning for the intended context.

Adjusted Shear Resistance. In Type II shear walls, the unadjusted shear resistance multiplied by
the shear resistance adjustment factor.

**Allowable Strength.** Nominal strength divided by the safety factor $R_n/\Omega$. [USA and Mexico]

**Applicable Building Code.** The building code under which the building is designed.

**Approved.** Acceptable to the authority having jurisdiction.

**ASD (Allowable Strength Design).** Method of proportioning structural components such that the allowable strength equals or exceeds the required strength of the component under the action of the ASD load combinations. [USA and Mexico]

**ASD Load Combination.** Load combination in the applicable building code intended for allowable strength design (allowable stress design). [USA and Mexico]

**Authority Having Jurisdiction.** An organization, political subdivision, office, or individual charged with the responsibility of administering and enforcing the provisions of the applicable building code.

**Available Strength.** Design strength or allowable strength, as appropriate. [USA and Mexico]

**Base Steel Thickness.** The thickness of bare steel exclusive of all coatings.

**Bearing Stiffener.** Additional material that is attached to the web to strengthen the member against web crippling. Also called a web stiffener.

**Blocking.** C-shaped member, break shape, flat strap material, or component assemblies attached to structural members, flat strap or sheathing panels to transfer shear forces or stabilize members.

**Blocking, Panel.** Blocking that transmits shear between the panels of a shear wall or diaphragm.

**Blocking, Stud.** Blocking that provides torsional restraint to the studs in a shear wall.

**Bracing.** Structural elements that are installed to provide restraint or support (or both) to other structural members or nonstructural members so that the complete assembly forms a stable structure.

**Ceiling Joist.** A horizontal structural member that supports ceiling components and which may be subject to attic loads.

**Chord.** Member of a shear wall, strap braced wall or diaphragm that forms the perimeter, interior opening, discontinuity or re-entrant corner.

**Chord Member.** A structural member that forms the top or bottom component of a truss.

**Chord Splice.** The connection region between two truss chord members where there is no change in slope.

**Chord Stud.** Axial load-bearing studs located at the ends of Type I shear walls or Type II shear wall segments or strap braced walls.

**Clip Angle.** An L-shaped short piece of steel typically used for connections.

**Cold-Formed Sheet Steel.** Sheet steel or strip steel that is manufactured by (1) press braking blanks sheared from sheets or cut length of coils or plates, or by (2) continuous roll forming of cold- or hot-rolled coils of sheet steel; both forming operations are performed at ambient room temperature, that is, without any addition of heat such as would be required for hot forming.

**Cold-Formed Steel.** See Cold-Formed Sheet Steel.

**Collector.** Also known as a drag strut, a member parallel to the applied load that serves to transfer forces between diaphragms and members of the lateral force-resisting system or distributes forces within the diaphragm.

**Component.** See Structural Component.

**Component Assembly.** A fabricated assemblage which consists primarily of cold-formed steel.
structural members that is manufactured by the component manufacturer.

Component Manufacturer. The individual or organization responsible for the manufacturing of component assemblies for the project. Also referred to as truss manufacturer on projects involving trusses, but hereinafter will be referred to as component manufacturer.

Connection. Combination of structural elements and joints used to transmit forces between two or more members.

Connector. A device used to transmit forces between cold-formed steel structural members, or between a cold-formed steel structural member and another structural element.

Contractor. Owner of the building, or the person that contracts with the owner, who constructs or manages the construction of the building in accordance with the construction documents. Also referred to as owner’s representative for construction, but hereinafter will be referred to as contractor.

Construction Documents. Written, graphic and pictorial documents prepared or assembled for describing the design (including the structural system), location and physical characteristics of the elements of a building necessary to obtain a building permit and construct a building.

Cripple Stud. A stud that is placed between a header and a window or door head track, a header and wall top track, or a window sill and a bottom track to provide a backing to attach finishing and sheathing material.

C-Shape. A cold-formed steel shape used for structural members and nonstructural members consisting of a web, two (2) flanges and two (2) lips (edge stiffeners).

Curtain Wall. A wall that transfers transverse (out-of-plane) loads and is limited to a superimposed vertical load, exclusive of sheathing materials, of not more than 100 lb/ft (1.46 kN/m), or a superimposed vertical load of not more than 200 lbs (0.890 kN).

Deflection Track. A track manufactured with extended flanges and used at the top of a wall to provide for vertical movement of the structure, independent of the wall stud.

Design Load. Applied load determined in accordance with either LRFD load combinations or ASD load combinations, whichever is applicable. [USA and Mexico]

Design Strength. Resistance factor multiplied by the nominal strength. [USA and Mexico]

Design Thickness. The steel thickness used in design.

Designation Thickness. The minimum base steel thickness expressed in mils and rounded to a whole number.

Diaphragm. Roof, floor or other membrane or bracing system that transfers in-plane forces to the lateral force-resisting system.

Eave Overhang. The horizontal projection of the roof measured from the outside face of exterior wall framing to the outside edge of the roof.

Edge Stiffener. See Lip.

Factored Load. Product of a load factor and the nominal load [specified load].

Factored Resistance. Product of nominal resistance and appropriate resistance factor. [Canada]

Fiberboard. A fibrous, homogeneous panel made from lignocellulosic fibers (usually wood or cane) and having a density of less than 31 pounds per cubic foot (pcf) (497 kg/m³) but more than 10 pcf (160 kg/m³).

Flange. For a C-shape, U-shape or track, that portion of the structural member or nonstructural member that is perpendicular to the web. For a furring channel, that portion of the structural member or nonstructural member that connects the webs.
Floor Joist. A horizontal structural member that supports floor loads and superimposed vertical loads.

Girt. Horizontal structural member that supports wall panels and is primarily subjected to bending under horizontal loads, such as wind load.

Grade. The designation of the minimum yield strength.

Gusset Plate. A structural member used to facilitate the connection of truss chord or web members at a heel, ridge, other pitch break, or panel point.

Hat-Shape. A singly symmetric shape consisting of at least two vertical webs and a horizontal stiffened flange which is used as a chord member in a truss.

Header. A horizontal structural member used over floor, roof or wall openings to transfer loads around the opening to supporting structural members.

Heel. The connection region between the top and bottom truss chords of a non-parallel chord truss.

Hold-Down (Tie-Down). A device used to resist overturning forces in a shear wall or strap braced wall, or uplift forces in a cold-formed steel structural member.

Inspection. When used in conjunction with quality control and quality assurance, it shall mean the systematic examination and review of the work for compliance with the appropriate documents, with appropriate subsequent documentation.

Installation Drawings. Drawings that show the location and installation of the cold-formed steel structural framing. Also referred to as truss placement diagram for truss construction.

Installer. Party responsible for the installation of cold-formed steel light-frame construction.

Jack Stud. A stud that does not span the full height of the wall and provides bearing for headers.

Joist. A structural member primarily used in floor and ceiling framing.

King Stud. A stud, adjacent to a jack stud, that spans the full height of the wall and supports vertical and lateral loads.

Lateral Force-Resisting System. The structural elements and connections required to resist racking and overturning due to wind forces or seismic forces, or other predominantly horizontal forces, or combination thereof, imposed upon the structure in accordance with the applicable building code.

Light-Frame Construction. Construction where the vertical and horizontal structural elements are primarily formed by a system of repetitive cold-formed steel or wood framing members.

Limit States. Those conditions in which a structural member ceases to fulfill the function for which it was designed. Those states concerning safety are called the ultimate limit states. The ultimate limit state for strength is the maximum load-carrying capacity. Limit states that restrict the intended use of a member for reasons other than safety, such as deflection and vibration, are called serviceability limit states. [Canada]

Lip. That part of a structural or nonstructural member that extends from the flange as a stiffening element.

Load. Force or other action that results from the weight of building materials, occupants and their possessions, environmental effects, differential movement, or restrained dimensional changes.

Load Effect. Forces, stresses, and deformations produced in a structural component by the applied loads.

Load Factor. Factor that accounts for deviations of the actual load from the nominal load, for
uncertainties in the analysis that transforms the load into a load effect, and for the probability that more than one extreme load will occur simultaneously. [USA and Mexico]

LRFD (Load and Resistance Factor Design). Method of proportioning structural components such that the design strength equals or exceeds the required strength of the component under the action of the LRFD load combinations. [USA and Mexico]

LRFD Load Combination. Load combination in the applicable building code intended for strength design (Load and Resistance Factor Design). [USA and Mexico]

LSD (Limit States Design). Method of proportioning structural components (members, connectors, connecting elements and assemblages) such that no applicable limit state is exceeded when the structure is subjected to all appropriate load combinations. [Canada]

Mean Roof Height. The average of the roof eave height and the height to the highest point on the roof surface, except that eave height shall be used for roof angles less than or equal to 10 degrees (0.18 rad).

Mil. A unit of measurement equal to 1/1000 inch.

Multiple Span. The span made by a continuous member having intermediate supports.

Nominal Load. Magnitude of the load specified by the applicable building code. [USA and Mexico]

Nominal Resistance (Resistance). Capacity of a structure or component to resist the effects of loads, determined in accordance with this Standard using specified material strengths and dimensions. [Canada]

Nominal Strength. Strength of a structure or component (without the resistance factor or safety factor applied) to resist the load effects, as determined in accordance with this Standard. [USA and Mexico]

Nonstructural Member. A member in a steel-framed system that is not a part of the gravity load-resisting system, lateral force-resisting system or building envelope.

Owner. The individual or entity organizing and financing the design and construction of the project.

Panel Point. The connection region between a web member and chord member in a truss.

Pitch Break. The connection region between two truss chord members where there is a change in slope, excluding the heel.

Plans. Also referred to as construction drawings. Drawings prepared by the building designer for the owner of the project. These drawings include but are not limited to floor plans, framing plans, elevations, sections, details and schedules as necessary to define the desired construction.

Plan Aspect Ratio. The ratio of the length (longer dimension) to the width (shorter dimension) of the building.

Punchout. A hole made during the manufacturing process in the web of a steel framing member.

Purlin. Horizontal structural member that supports roof deck and is primarily subjected to bending under vertical loads such as snow, wind, or dead loads.

Quality Assurance. Monitoring and inspection tasks performed by a registered design professional, firm or approved agency other than the component manufacturer or installer to ensure that the material provided and work performed by the component manufacturer and installer meet the requirements of the approved construction documents and referenced standards. Quality assurance includes those tasks designated “special inspection” by the applicable building code.
Quality Assurance Inspector. Individual or agency designated to provide quality assurance inspection for the work being performed.

Quality Control. Controls and inspections implemented by the component manufacturer or installer to confirm that the material provided and work performed meet the requirements of the approved construction documents and referenced standards.

Quality Control Inspector. Individual or agency designated to perform quality control inspection tasks for the work being performed.

Quality Control Program. Program in which the component manufacturer or installer, as applicable, maintains detailed assembly or installation and inspection procedures to ensure conformance with the approved installation drawings, plans, specifications and referenced standards.

Rake Overhang. The horizontal projection of the roof measured from the outside face of a gable endwall to the outside edge of the roof.

Rational Engineering Analysis. Analysis based on theory that is appropriate for the situation, any relevant test data, if available, and sound engineering judgment.

Registered Design Professional. Architect or engineer who is licensed to practice their respective design profession as defined by the legal requirements of the jurisdiction in which the building is to be constructed.

Repetitive Framing. A framing system where the wall, floor and roof structural members are spaced no greater than 24 inches (610 mm) on center. Larger spaces are permitted at openings where the structural loads are transferred to headers or lintels and supporting studs, joists or rafters.

Required Strength. Forces, stresses, and deformations produced in a structural component, determined by either structural analysis, for the LRFD or ASD load combinations, as appropriate, or as specified by this Standard. [USA and Mexico]

Resistance Factor (φ). Factor that accounts for unavoidable deviations of the actual strength from the nominal strength [nominal resistance] and for the manner and consequences of failure.

Ridge. The horizontal line formed by the joining of the top edges of two upward sloping roof surfaces.

Rim Track. A horizontal structural member that is connected to the end of a floor joist.

Risk Category. A categorization of buildings and other structures for determination of flood, wind, snow, ice, and earthquake loads based on the risk associated with unacceptable performance.

Roof Rafter. A horizontal or sloped, structural member that supports roof loads.

Safety Factor (Ω). Factor that accounts for the desired level of safety, including deviations of the actual load from the nominal load and uncertainties in the analysis that transforms the load into a load effect, in determining the nominal strength and for the manner and consequences of failure. [USA and Mexico]

Seismic Design Category (SDC). A classification assigned by the applicable building code to a structure based upon its risk category and the severity of the design earthquake ground motion at the site.

Seismic Force-Resisting System. That part of the structural system that has been selected in the design to provide energy dissipation and the required resistance to seismic forces prescribed in the applicable building code.

Shear Wall. A wall with structural sheathing attached to cold-formed steel structural members and
designed to primarily resist lateral forces parallel to the wall.

*Shop Drawings.* Drawings for the production of individual *component assemblies* for the project.

*Single Span.* The span made by one continuous *structural member* without any intermediate supports.

*Span.* The clear horizontal distance between bearing supports.

*Specifications.* Written instructions, which, with the plans, define the materials, standards, design of the products, and workmanship expected on a construction project.

*Specified Load.* Magnitude of the load specified by the *applicable building code*, not including *load factors*. [Canada]

*Static Load.* A *load* or series of *loads* that are supported by or are applied to a structure so gradually that forces caused by change in momentum of the load and structural elements can be neglected and all parts of the system at any instant are essentially in equilibrium.

*Steel Sheet Sheathing.* A panel of thin flat steel sheet.

*Strap.* Flat or coiled sheet steel material typically used for *bracing* or *blocking*, which transfers *loads* by tension or shear.

*Strap Braced Wall.* A wall with *strap bracing* attached to *cold-formed steel structural members* and designed to primarily resist lateral forces parallel to the wall.

*Strap Bracing.* Steel *straps* applied diagonally to form a vertical *truss* that forms part of the lateral force-resisting system.

*Structural Component.* Member, connector, connecting element or assemblage.

*Structural Member.* A member that resists *design loads* [*factored loads*], as required by the *applicable building code*, except when defined as a *nonstructural member*.

*Structural Sheathing.* The structural sheathing that is capable of distributing *loads*, *bracing* members, and providing additional stability that strengthens the assembly.

*Stud.* A vertical *structural member* or *nonstructural member* in a wall system or assembly.

*Track.* A *structural member* or *nonstructural member* consisting of only a *web* and two (2) *flanges*. *Track web* depth measurements are taken to the inside of the flanges.

*Truss.* A coplanar system of *structural members* joined together at their ends typically to construct a series of triangles that form a stable beam-like framework.

*Truss Design Drawing.* Written, graphic and pictorial depiction of an individual *truss*.

*Truss Design Engineer.* Person who is licensed to practice engineering as defined by the legal requirements of the jurisdiction in which the building is to be constructed and who supervises the preparation of the *truss design drawings*.

*Truss Designer.* Person responsible for the preparation of the *truss design drawings*.

*Truss Manufacturer.* An individual or organization engaged in the manufacturing of site-built or in-plant *trusses*.

*Truss Member.* A *chord member* or *web member* of a *truss*.

*Type I Shear Wall.* Wall designed to resist in-plane lateral forces that is fully sheathed and that is provided with *hold-downs* at each end of the wall segment.

*Type II Shear Wall.* Wall designed to resist in-plane lateral forces that is sheathed with *wood structural panels* or *steel sheet sheathing* that contains openings, but which has not been specifically designed and detailed for force transfer around wall openings. *Hold-downs* for *Type II shear walls* are only required at the ends of the wall.

*Type II Shear Wall Segment.* Section of *shear wall* (within a *Type II shear wall*) with full-height sheathing (i.e., with no openings) and which meets specific aspect ratio limits.

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Wall Pier. A section of a Type I shear wall adjacent to an opening and equal in height to the opening, which is designed to resist lateral forces in the plane of the wall.

Web. That portion of a structural member or nonstructural member that connects the flanges.

Web Member. A structural member in a truss that is connected to the top and bottom chords, but is not a chord member.

Wind Exposure. Wind exposure in accordance with the applicable building code.

Wood Structural Panel. A panel manufactured from veneers, wood strands or wafers or a combination of veneer and wood strands or wafers bonded together with waterproof synthetic resins or other suitable bonding systems.

Yield Strength. Stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain as defined by ASTM.

Z-Shape. A point-symmetric or non-symmetric section that is used as a chord member in a truss.

A3 Material

A3.1 Structural members utilized in cold-formed steel light-frame construction shall be cold-formed to shape from sheet steel complying with the requirements of ASTM A1003/A1003M, subject to the following limitations:

(a) Type H (high ductility): No limitations.
(b) Type L (low ductility): Limited to purlins, girts and curtain wall studs. Additional country-specific limitations for curtain wall studs are provided in Section A2.3.5 of AISI S100 [CSA S136].

A3.2 In Canada, structural members are permitted to be cold-formed to shape from sheet steel complying with the requirements of ASTM A653/A653M Type SS or ASTM A792/A792M Type SS.

A4 Corrosion Protection

A4.1 Structural members utilized in cold-formed steel light-frame construction shall have a protective coating as specified in Table A4-1.

<table>
<thead>
<tr>
<th>Coating Classification</th>
<th>Coating Designator</th>
<th>Minimum Coating Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc Coated</td>
<td>Zinc Iron</td>
<td>55% Al-Zinc</td>
</tr>
<tr>
<td>ozt/ft² (g/m²)</td>
<td>ozt/ft² (g/m²)</td>
<td>ozt/ft² (g/m²)</td>
</tr>
<tr>
<td>Metallic Coated</td>
<td>CP 60</td>
<td>G60 [Z180]</td>
</tr>
<tr>
<td></td>
<td>CP 90</td>
<td>G90 [Z275]</td>
</tr>
<tr>
<td>Painted Metallic</td>
<td>PM</td>
<td>The metallic coated substrate shall meet the requirements of metallic coated. In addition, the paint film shall have a minimum thickness of 0.5 mil per side (primer plus topcoat) with a minimum primer thickness of 0.1 mil per side.</td>
</tr>
</tbody>
</table>

A4.1.1 In Canada, structural members utilized in cold-formed steel light-frame construction shall have a metallic coating of G60 [Z180] complying with the requirements of ASTM A653/A653M or AZ50 [AZM150] complying with the requirements of ASTM A792/A792M.
A4.2 Additional corrosion protection shall not be required on edges of metallic-coated steel framing members, where shop or field cut, punched or drilled.

A4.3 Unless additional corrosion protection is provided, framing members shall be located within the building envelope and shielded from direct contact with moisture from the ground or the exterior climate.

A4.4 Dissimilar metals shall not be used in direct contact with cold-formed steel framing members unless approved for that application.

A4.5 Cold-formed steel framing members shall not be embedded in concrete unless approved for that application.

A4.6 Fasteners shall have a corrosion-resistant treatment, or be manufactured from material not susceptible to corrosion.

A5 Products

A5.1 Base Steel Thickness

The material thickness of framing members, in their end-use, shall meet or exceed the minimum base steel thickness values given in the approved construction documents. In no case shall the minimum base steel thickness be less than 95% of the design thickness.

A5.2 Minimum Flange Width

Where intended for sheathing attachment, C-shape members shall have a minimum flange width of 1-1/4 inch (31.8 mm). For track members, the minimum flange width shall be 3/4 inch (19.1 mm).

A5.3 Product Designator

A5.3.1 A four-part product designator that identifies the size (both web depth and flange width), type, and thickness shall be used for reference to structural members. The product designator as described (i.e., based on U.S. Customary units) shall be used for either U.S. Customary or SI Metric units. The product designator shall consist of the following sequential codes:

(a) A three- or four-digit numeral indicating member web depth in 1/100 inch.

(b) A letter indicating member type, in accordance with the following:

   S = Stud or joist framing member which has lips
   T = Track section
   U = Channel or stud framing section which does not have lips
   F = Furring channels
   L = Angle or L-header

(c) A three-digit numeral indicating flange width in 1/100 inch, followed by a dash.

(d) A two- or three-digit numeral indicating designation thickness.

A5.3.2 The material grade used in design shall be identified on the construction documents and when ordering the material.

A5.4 Manufacturing Tolerances

Structural members utilized in cold-formed steel light-frame construction shall comply with the manufacturing tolerances listed in Table A5-1, as illustrated in Figure A5-1. All measurements shall be taken not less than 1 ft (305 mm) from the end of the member.
### Table A5-1
Manufacturing Tolerances for Structural Members

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Item Checked</th>
<th>Studs, in. (mm)</th>
<th>Tracks, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Length</td>
<td>+3/32 (2.38)</td>
<td>+ 1/2 (12.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-3/32 (2.38)</td>
<td>-1/4 (6.35)</td>
</tr>
<tr>
<td>B²</td>
<td>Web Depth</td>
<td>+1/32 (0.79)</td>
<td>+1/32 (0.79)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-1/32 (0.79)</td>
<td>+1/8 (3.18)</td>
</tr>
<tr>
<td>C</td>
<td>Flare</td>
<td>+1/16 (1.59)</td>
<td>+0 (0)</td>
</tr>
<tr>
<td></td>
<td>Overbend</td>
<td>-1/16 (1.59)</td>
<td>-3/32 (2.38)</td>
</tr>
<tr>
<td>D</td>
<td>Hole Center</td>
<td>+1/16 (1.59)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Width</td>
<td>-1/16 (1.59)</td>
<td>NA</td>
</tr>
<tr>
<td>E</td>
<td>Hole Center</td>
<td>+1/4 (6.35)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>-1/4 (6.35)</td>
<td>NA</td>
</tr>
<tr>
<td>F</td>
<td>Crown</td>
<td>+1/16 (1.59)</td>
<td>+1/16 (1.59)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-1/16 (1.59)</td>
<td>-1/16 (1.59)</td>
</tr>
<tr>
<td>G³</td>
<td>Camber</td>
<td>1/8 per 10 ft (3.13 per 3 m)</td>
<td>1/32 per ft (2.60 per m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1/2 max (12.7)</td>
<td>1/2 max (12.7)</td>
</tr>
<tr>
<td>H³</td>
<td>Bow</td>
<td>1/8 per 10 ft (3.13 per 3 m)</td>
<td>1/32 per ft (2.60 per m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1/2 max (12.7)</td>
<td>1/2 max (12.7)</td>
</tr>
<tr>
<td>I</td>
<td>Twist</td>
<td>1/32 per ft (2.60 per m)</td>
<td>1/32 per ft (2.60 per m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1/2 max (12.7)</td>
<td>1/2 max (12.7)</td>
</tr>
<tr>
<td>J</td>
<td>Flange</td>
<td>+1/8 (3.18)</td>
<td>+1/4 (6.35)</td>
</tr>
<tr>
<td></td>
<td>Width</td>
<td>-1/16 (1.59)</td>
<td>-1/16 (1.59)</td>
</tr>
<tr>
<td>K</td>
<td>Stiffening Lip</td>
<td>+1/8 (3.18)</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>-1/32 (0.79)</td>
<td></td>
</tr>
</tbody>
</table>

1. All measurements are taken not less than 1 ft (305 mm) from the end.
2. Outside dimension for stud; inside for track.
3. 1/8 inch per 10 feet represents L/960 maximum for overall camber and bow. Thus, a 20-foot-long member has 1/4 inch permissible maximum; a 5-foot-long member has 1/16-inch permissible maximum.

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**Figure A5-1 Manufacturing Tolerances for Structural Members**

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A5.5 Product Identification

Framing members used in cold-formed steel light-frame construction shall be identified in accordance with the requirements of this section.

A5.5.1 Identification of Groups of Like Members

Groups of like members shall be marked with a label, or a tag attached thereto. Marking shall include the roll-former’s identification (name, logo, or initials), length, quantity, and roll-former’s member designator including member depth, flange size, and minimum steel thickness in mils or inches exclusive of protective coating.

A5.5.2 Identification of Individual Framing Members

A5.5.2.1 In the United States and Mexico, in addition to the marking referenced in A5.5.1, individual framing members shall have a legible label, stencil, or embossment, at a maximum distance of 96 in. (2440 mm) on center, on the member, with the following minimum information:

(a) The rollformer’s identification (i.e., name, logo, or initials).
(b) The minimum steel thickness, in mils or inches, exclusive of protective coating.
(c) The minimum yield strength in kips per square inch [megapascals].
(d) The appropriate protective coating designator in accordance with Section A4.

A5.5.2.2 In Canada, in addition to the marking referenced in A5.5.1, individual framing members shall have a legible label, stencil, or embossment, at a maximum distance of 96 in. (2440 mm) on center, on the member, with the following minimum information:

(a) The manufacturer’s identification (name, logo, or initials); and
(b) The minimum steel thickness (in mils, inches or millimeters) exclusive of protective coatings.

A6 Reference Documents

The following documents or portions thereof are referenced within this Standard and shall be considered as part of the requirements of this document.

1. American Society of Civil Engineers, Reston, VA

2. American Iron and Steel Institute, Washington, DC
   AISI S100-12, North American Specification for the Design of Cold-Formed Steel Structural Members
   AISI S202-15, Code of Standard Practice for Cold-Formed Steel Structural Framing
   AISI S901-13, Rotational-Lateral Stiffness Test Method for Beam-to-Panel Assemblies
   AISI S902-13, Stub-Column Test Method for Effective Area of Cold-Formed Steel Columns
   AISI S903-13, Standard Methods for Determination of Uniform and Local Ductility
   AISI S904-13, Standard Test Methods for Determining the Tensile and Shear Strength of Screws
   AISI S905-13, Test Standard for Cold-Formed Steel Connections
   AISI S907-13, Test Standard for Cantilever Test Method for Cold-Formed Steel Diaphragms
   AISI S909-13, Standard Test Method for Determining the Web Crippling Strength of Cold-Formed
Steel Beams
AISI S910-13, Test Method for Distortional Buckling of Cold-Formed Steel Hat-Shaped Compression Members
AISI S911-13, Method for Flexural Testing of Cold-Formed Steel Hat-Shaped Beams
AISI S913-13, Test Standard for Hold-Downs Attached to Cold-Formed Steel Structural Framing
AISI S914-15, Test Standard for Joist Connectors Attached to Cold-Formed Steel Structural Framing
AISI S915-15, Test Standard for Through-The-Web Punchout Cold-Formed Steel Wall Stud Bridging Connectors

3. ASTM International, West Conshohocken, PA
ASTM A653/A653M-15, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM A792/A792M-10, Standard Specification for Steel Sheet, 55% Aluminum-Zinc Alloy-Coated by the Hot-Dip Process
ASTM A875/A875M-13, Standard Specification for Steel Sheet, Zinc-5% Aluminum Alloy-Coated by the Hot-Dip Process
ASTM A1003/A1003M-15, Standard Specification for Steel Sheet, Carbon, Metallic- and Nonmetallic-Coated for Cold-Formed Framing Members
ASTM C208-12, Standard Specification for Cellulosic Fiber Insulating Board
ASTM C954–15, Standard Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs From 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness
ASTM C1002–14, Standard Specification for Steel Self-Piercing Tapping Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Wood Studs or Steel Studs
ASTM C1396/C1396M–14a, Standard Specification for Gypsum Board
ASTM C1513-13, Standard Specification for Steel Tapping Screws for Cold-Formed Steel Framing Connections
ASTM E455-11, Standard Method for Static Load Testing of Framed Floor or Roof Diaphragm Constructions for Buildings
ASTM E2126-11, Standard Test Methods for Cyclic (Reversed) Load Test for Shear Resistance of Vertical Elements of the Lateral Force Resisting Systems for Buildings

4. American Welding Society, Miami, FL
AWS B5.1, Specification for the Qualification of Welding Inspectors, 2003 Edition

5. CSA Group, Mississauga, Ontario, Canada
CSA O325-07 (R2012), Construction Sheathing
CAN/CSA-S136-12, North American Specification for the Design of Cold-Formed Steel Structural Members
CSA O121-08 (R2013), Douglas Fir Plywood
CSA O151-09 (R2014), Canadian Softwood Plywood
CSA O325-07(R2012), Construction Sheathing
CSA O437-93 (R2011), Standards on OSB and Waferboard

6. Department of Commerce Voluntary Product Standard, administered by NIST, Gaithersburg, MD
DOC PS 1-09, Structural Plywood

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DOC PS 2-10, *Performance Standard for Wood-Based Structural-Use Panels*

7. National Research Council of Canada, Ottawa, Ontario, Canada
B. DESIGN

B1 General

The provisions in Section B1 shall be used in conjunction with the requirements in Sections B2 through B5, as applicable.

B1.1 Loads and Load Combinations

Buildings or other structures and all parts therein shall be designed in accordance with the applicable building code to support all loads that are expected during its life. In the absence of an applicable building code, the loads, forces, and combinations of loads shall be in accordance with accepted engineering practice for the location under consideration as specified by the applicable sections of ASCE 7, Minimum Design Loads for Buildings and Other Structures in the United States and Mexico, or the National Building Code of Canada in Canada.

B1.1.1 Application of Live Load Reduction on Wall Studs

For the purpose of calculating the design axial load on a wall using floor live load reduction requirements in accordance with the applicable building code, the tributary area of the wall shall be limited to the floor area assigned to the individual wall framing members.

B1.1.2 Application of Wind Loads on Wall Studs in the United States and Mexico

In the United States and Mexico, the design of the wall studs shall be based on the following design wind loads:

(a) Combined bending and axial load effect based on Main Wind Force-Resisting System (MWFRS) wind loads.
(b) Bending load effect based on Components and Cladding (C&C) wind loads.
(c) Deflection limits based on 42% of Components and Cladding (C&C) wind loads with no axial loads.

B1.2 Design Basis

The proportioning, designing and detailing of cold-formed steel light-frame lateral force-resisting systems, trusses, structural members, connections and connectors shall be in accordance with AISI S100 [CSA S136], and the reference documents except as modified or supplemented by the requirements of this Standard.

B1.2.1 Floor Joists, Ceiling Joists and Roof Rafters

B1.2.1.1 Floor joists, ceiling joists and roof rafters shall be designed either on the basis of discretely braced design or on the basis of continuously braced design, in accordance with the following:

(a) Discretely Braced Design. Floor and roof assemblies using discretely braced design shall be designed neglecting the structural bracing and composite-action contribution of attached sheathing or deck. Discretely braced design shall include assemblies where the sheathing or deck is not attached directly to structural members.
(b) Continuously Braced Design. Unless noted otherwise in Section B2 or B4, the continuously braced design requirements of this Standard shall be limited to
floor joists, ceiling joists and roof rafters that comply with all of the following conditions:

1. Maximum web depth = 14 inches (356 mm)
2. Maximum design thickness = 0.1242 inches (3.155 mm)
3. Minimum design yield strength, $F_y = 33$ ksi (230 MPa)
4. Maximum design yield strength, $F_y = 50$ ksi (345 MPa)

B1.2.1.2 Where continuously braced design is used, the construction documents shall identify the sheathing or deck as a structural element.

B1.2.1.3 A web with one or more holes shall be designed in accordance with AISI S100 [CSA S136], or reinforced in accordance with an approved design or as specified by a registered design professional.

B1.2.2 Wall Studs

B1.2.2.1 Wall studs shall be designed either on the basis of all steel design or on the basis of sheathing braced design, in accordance with the following:

(a) All Steel Design. Wall stud assemblies using all steel design shall be designed neglecting the structural bracing and composite-action contribution of the attached sheathings.

(b) Sheathing Braced Design. Wall stud assemblies using sheathing braced design shall have sheathing attached to both flanges of the wall stud or sheathing attached to the one flange and discrete bracing to the other flange. The stud shall be connected to the bottom and top track or other horizontal member(s) of the wall to provide lateral and torsional support to the wall stud in the plane of the wall. Wall studs with sheathing attached to both sides that is not identical shall be designed based on the assumption that the weaker of the two sheathings is attached to both sides.

B1.2.2.2 When sheathing braced design is used, the construction documents shall identify the sheathing as a structural element.

B1.2.2.3 For curtain wall studs, the combination of sheathing attached to one side of the wall stud and discrete bracing for the other flange is permitted. The spacing of discrete bracing shall be no greater than 8 ft (2.44 m) on center. For design, the nominal flexural strength [resistance] shall be determined by AISI S100 Section C3.1. When the compression flange has sheathing attached, AISI S100 Section C3.1.1 is permitted. When the compression flange does not have sheathing attached, AISI S100 Section C3.1.2 shall apply. In both cases, AISI S100 Section C3.1.4 for distortional buckling shall also be considered.

B1.2.2.4 In the United States and Mexico, when sheathing braced design is used, the wall studs shall also be evaluated without the sheathing bracing for the following load combination:

$$1.2D + (0.5L \text{ or } 0.2S) + 0.2W$$

(Eq. B1.2.2-1)

where

$D =$ Dead load
$L =$ Live load
$S =$ Snow load
$W =$ Wind load

B1.2.2.5 In Canada, the provisions for sheathing braced design shall be in accordance
with a theory, tests, or rational engineering analysis and shall comply with Chapter C of AISI S100 [CSA S136], as applicable.

B1.2.2.6 A web with one or more holes shall be designed in accordance with AISI S100 [CSA S136].

B1.2.3 In-Line Framing

B1.2.3.1 Each joist, rafter, truss, and structural wall stud (above or below) shall be aligned vertically in accordance with the limits depicted in Figure B1.2.3-1.

B1.2.3.2 The alignment tolerance shall not be required to be met when a structural load distribution member is specified in accordance with the approved construction documents.

B1.2.4 Sheathing Span Capacity

B1.2.4.1 Floor joist and floor truss spacing shall be limited by the span capacity of the floor structural sheathing material.

B1.2.4.2 Wall stud spacing shall be limited by the span capacity of the wall structural sheathing material.

B1.2.4.3 The spacing of roof and ceiling framing members shall be limited by the span capacity of the ceiling or roof structural sheathing material.

B1.2.5 Load Path

A continuous load path to the foundation shall be provided for the uplift, shear, and
compression forces due to lateral wind forces, seismic forces, or other predominantly horizontal forces, or combinations thereof, imposed upon the structure in accordance with the *applicable building code*. Elements resisting forces contributed by multiple stories shall be designed for the sum of forces contributed by each story in conformance to *applicable building code*.

**B1.2.6 Principles of Mechanics**

Where *cold-formed steel structural members* and *connections* are not required to be designed in accordance with the additional provisions of Section A1.3, the provisions of this section are permitted for *lateral force-resisting systems*.

**B1.2.6.1** The shear resistance of *shear walls*, *strap braced walls* and *diaphragms* is permitted to be determined by principles of mechanics using values of fastener strength, sheathing shear resistance, and *strap* strength, as applicable.

**B1.2.6.2** When determined by the principles of mechanics, the *nominal strength* [*nominal resistance*] defines the maximum resistance that the *diaphragm*, *shear wall*, or *strap braced wall* is capable of developing.

**B1.2.6.3** Required *strength* [*effect of factored loads*] shall be determined in accordance with the force requirements in the *applicable building code*.

**B1.2.6.4** When determined by the principles of mechanics, values for systems defined in this Standard shall be scaled to the values in this Standard.

**B1.3 Built-Up Section Design**

Built-up sections shall be evaluated in accordance with Section D1 of AISI S100 [CSA S136] and the additional requirements of Sections B1.3.1 and B1.3.2, as applicable.

**B1.3.1** For either all steel design or sheathing braced design, the *available strength* [*factored resistance*] of built-up sections shall be determined in accordance with Section D1.2 of AISI S100 [CSA S136].

*Exception:* Where a built-up axial *load* bearing section comprised of two *studs* oriented back-to-back forming an I-shaped cross-section is seated in a *track* in accordance with the requirements of Section C3.4.3 and the top and bottom end bearing detail of the *studs* consists of support by steel or concrete components with adequate strength and stiffness to preclude relative end slip of the two built-up *stud* sections, the compliance with the end *connection* provisions of AISI S100 Section D1.2(b) is not required.

**B1.3.2** When the *connection* requirements of Section D1.2 of AISI S100 [CSA S136] or the exception permitted in B1.3.1 are not met, the *available strength* [*factored resistance*] of built-up sections shall be equal to the sum of the *available strengths* [*factored resistances*] of the individual members of the built-up cross-section.

**B1.4 Properties of Sections**

The properties of sections shall be full cross-section properties, except where use of a reduced cross-section or effective design width is required by AISI S100 [CSA S136].

**B1.5 Connection Design**

*Connections* using screws, welds, bolts, or power-actuated fasteners shall be designed in accordance with AISI S100 [CSA S136] and the additional requirements of this Standard. For *connections* using other fastener types, design values [*factored resistances*] shall be determined...
by testing in accordance with Section F1 of AISI S100 [CSA S136].

**B1.5.1 Screw Connections**

**B1.5.1.1 Steel-to-Steel Screws**

Screw fasteners for steel-to-steel connections shall be in compliance with ASTM C1513 or the approved construction documents.

**B1.5.1.2 Sheathing Screws**

Screw fasteners for structural sheathing to steel connections shall be in compliance with ASTM C1513 or the approved construction documents.

**B1.5.1.3 Spacing and Edge Distance**

**B1.5.1.3.1** For screw fasteners in steel-to-steel connections to be considered fully effective, the minimum edge distance shall be 3 times the nominal diameter.

**Exception:** Where the edge is parallel to the direction of the applied force, the minimum edge distance of screw fasteners shall be 1.5 times the nominal diameter.

**B1.5.1.3.2** For screw fasteners in steel-to-steel connections to be considered fully effective, the minimum center-to-center spacing shall be 3 times the nominal diameter.

**Exception:** Where the center-to-center spacing of screw fasteners in steel-to-steel connections is less than 3 times the nominal diameter but greater than or equal to 2 times the nominal diameter, screw fasteners shall be considered 80 percent effective.

**B1.5.1.4 Gypsum Board**

Screw fasteners for gypsum board to steel connections shall be bugle head style in compliance with ASTM C954, ASTM C1002, or ASTM C1513, as applicable.

**B1.5.2 Welded Connections**

Welded connections shall be in accordance with AISI S100 [CSA S136] and AWS D1.3. The design capacity of welds shall be in accordance with AISI S100 [CSA S136].

**B1.5.3 Bolts**

Bolted cold-formed steel connections shall be designed and installed in accordance with AISI S100 [CSA S136].

**B1.5.4 Power-Actuated Fasteners**

Cold-formed steel connections using power-actuated fasteners shall be designed and installed in accordance with AISI S100 [CSA S136].

**B1.5.5 Other Connectors**

Other types of connections (e.g., rivet fasteners and clinch joining) shall be designed, fabricated and installed in accordance with the design requirements as set forth by the approved construction documents and the fastener manufacturer’s requirements.
B1.5.6 Connection to Other Materials

Bolts, nails, anchor bolts or other fasteners used to connect cold-formed steel framing to wood, masonry, concrete or other steel components shall be designed and installed in accordance with the applicable building code or the approved construction documents.

B2 Floor and Ceiling Framing

The requirements in Section B2 shall be used in conjunction with the requirements in Section B1, as applicable.

B2.1 Scope

Sections B2.2 through B2.7 are applicable to floor and ceiling systems that utilize cold-formed steel structural members.

B2.2 Floor Joist Design

Floor joists shall be designed in accordance with the requirements of this section.

B2.2.1 Bending

The available bending strength [factored resistance] of floor joists shall be the lesser of the strengths determined in accordance with Sections B2.2.1.1 and B2.2.1.2.

B2.2.1.1 Lateral-Torsional Buckling

Floor joists shall be designed either on the basis of discretely braced design or on the basis of continuously braced design, in accordance with the following:
(a) Discretely Braced Design. For discretely braced design, flexure shall be evaluated in accordance with Section C3.1.2 of AISI S100 [CSA S136].
(b) Continuously Braced Design. For continuously braced design, where structural sheathing or steel deck is attached to the compression flange of the floor joist in accordance with Section B2.6(1) and the tension flange is braced in accordance with Section B2.6(2), flexure shall be evaluated in accordance with Section C3.1.1 of AISI S100 [CSA S136].

B2.2.1.2 Distortional Buckling

Floor joists shall be designed either on the basis of discretely braced design or on the basis of continuously braced design, in accordance with the following:
(a) Discretely Braced Design. For discretely braced design, flexure shall be evaluated in accordance with Section C3.1.4 of AISI S100 [CSA S136]. If the discrete bracing restricts rotation of the compression flange about the web/flange juncture, the distance between braces shall be used as \(L_m\) when applying AISI S100 [CSA S136].
(b) Continuously Braced Design. For continuously braced design, flexure shall be evaluated in accordance with Section C3.1.4 of AISI S100 [CSA S136]. The rotational stiffness, \(k_\phi\), provided by the sheathing or deck to the floor joist shall be determined in accordance with Appendix 1.

B2.2.2 Shear

Shear shall be evaluated in accordance with Section C3.2 of AISI S100 [CSA S136].
B2.2.3 Web Crippling

Web crippling shall be evaluated in accordance with Section C3.4 of AISI S100 [CSA S136], unless a bearing stiffener is used in accordance with the requirements of Section B2.5.1.

B2.2.4 Bending and Shear

The combination of flexure and shear shall be evaluated in accordance with Section C3.3 of AISI S100 [CSA S136].

B2.2.5 Bending and Web Crippling

The combination of flexure and web crippling shall be evaluated in accordance with Section C3.5 of AISI S100 [CSA S136], unless a bearing stiffener is used in accordance with the requirements of Section B2.5.1.

B2.3 Ceiling Joist Design

Ceiling joists shall be designed in accordance with the requirements of this section.

B2.3.1 Tension

Tension shall be evaluated in accordance with Section C2 of AISI S100 [CSA S136].

B2.3.2 Compression

The available compression strength [factored resistance] of ceiling joists shall be the lesser of the strengths determined in accordance with Sections B2.3.2.1 and B2.3.2.2.

B2.3.2.1 Yielding, Flexural, Flexural-Torsional and Torsional Buckling

Compression shall be evaluated in accordance with Section C4.1 of AISI S100 [CSA S136].

B2.3.2.2 Distortional Buckling

Ceiling joists shall be designed either on the basis of discretely braced design or on the basis of continuously braced design, in accordance with the following:

(a) Discretely Braced Design. For discretely braced design, compression shall be evaluated in accordance with Section C4.2 of AISI S100 [CSA S136]. If the discrete bracing restricts rotation of the compression flange about the web/flange juncture, the distance between braces shall be used as L_m when applying AISI S100 [CSA S136].

(b) Continuously Braced Design. For continuously braced design, compression alone shall be evaluated in accordance with Section C4.2 of AISI S100 [CSA S136]. The rotational stiffness, k_φ, provided by the sheathing or deck to the ceiling joist shall be determined in accordance with Appendix 1.

B2.3.3 Bending

The available flexural strength [resistance] of ceiling joists shall be the lesser of the strengths determined in accordance with Sections B2.3.3.1 and B2.3.3.2.

B2.3.3.1 Lateral-Torsional Buckling

Ceiling joists shall be designed either on the basis of discretely braced design or on
the basis of continuously braced design, in accordance with the following:

(a) Discretely Braced Design. For discretely braced design, flexure shall be evaluated in accordance with Section C3.1.2 of AISI S100 [CSA S136].

(b) Continuously Braced Design. For continuously braced design, where structural sheathing or steel deck is attached to the compression flange of the ceiling joist in accordance with Section B2.6 (1) and the tension flange is braced in accordance with Section B2.6(2), flexure for gravity loading shall be evaluated in accordance with Section C3.1.1 of AISI S100 [CSA S136] and flexure for uplift loading shall be evaluated in accordance with Sections C3.1.2 and D6.1.1 of AISI S100 [CSA S136].

B2.3.3.2 Distortional Buckling

Ceiling joists shall be designed either on the basis of discretely braced design or on the basis of continuously braced design, in accordance with the following:

(a) Discretely Braced Design. For discretely braced design, flexure shall be evaluated in accordance with Section C3.1.4 of AISI S100 [CSA S136]. If the discrete bracing restricts rotation of the compression flange about the web/flange juncture, the distance between braces shall be used as \( L_m \) when applying AISI S100 [CSA S136].

(b) Continuously Braced Design. For continuously braced design, flexure shall be evaluated in accordance with Section C3.1.4 of AISI S100 [CSA S136]. The rotational stiffness, \( k_\phi \), provided by the sheathing or deck to the ceiling joist shall be determined in accordance with Appendix 1.

B2.3.4 Shear

Shear shall be evaluated in accordance with Section C3.2 of AISI S100 [CSA S136].

B2.3.5 Web Crippling

Web crippling shall be evaluated in accordance with Section C3.4 of AISI S100 [CSA S136], unless a bearing stiffener is used in accordance with the requirements of Section B2.5.1.

B2.3.6 Axial Load and Bending

The combination of axial load and bending shall be evaluated in accordance with Section C5 of AISI S100 [CSA S136].

B2.3.7 Bending and Shear

The combination of flexure and shear shall be evaluated in accordance with Section C3.3 of AISI S100 [CSA S136].

B2.3.8 Bending and Web Crippling

The combination of flexure and web crippling shall be evaluated in accordance with Section C3.5 of AISI S100 [CSA S136], unless a bearing stiffener is used in accordance with the requirements of Section B2.5.1.

B2.4 Floor Truss Design

Floor trusses shall be designed in accordance with Chapter E.
B2.5 Bearing Stiffeners

Bearing stiffeners, other than clip angle bearing stiffeners, shall be designed in accordance with Section C3.7 of AISI S100 [CSA S136]. Clip angle bearing stiffeners, as permitted in Section B2.2.3, shall be designed in accordance with Section B2.5.1.

B2.5.1 Clip Angle Bearing Stiffeners

The nominal web crippling strength [resistance] of a floor joist connected to a rim track using a clip angle bearing stiffener shall be determined in accordance with the following:

\[ P_n = 0.9 \left( P_j + P_t + 0.5A_g F_y \right) \]  
(Eq. B2.5.1-1)

where

- \( P_j \) = Nominal end two-flange web crippling strength [resistance] of the floor joist determined in accordance with Section C3.4.1 of AISI S100 [CSA S136]
- \( P_t \) = Nominal interior two-flange web crippling strength [resistance] of the rim track determined in accordance with Section C3.4.1 of AISI S100 [CSA S136]
- \( A_g \) = Gross area of the clip angle bearing stiffener
- \( F_y \) = Yield strength of clip angle

The available strength [factored resistance] shall be determined using the safety factor (\( \Omega \)) or the resistance factor (\( \phi \)) as follows:

- \( \Omega_c = 1.80 \) for ASD
- \( \phi_c = 0.85 \) for LRFD
- \( \phi_c = 0.70 \) for LSD

Equation B2.5.1-1 shall be valid for the range of parameters listed in Table B2.5.1-1, as illustrated in Figure B2.5-1.

![Diagram of Fastening of Clip Angle Bearing Stiffener](image-url)
Table B2.5.1-1
Parameters for Equation B2.5.1-1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Joist and Rim Track:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Thickness</td>
<td>0.0451&quot; (1.146 mm)</td>
<td>0.1017&quot; (2.583 mm)</td>
</tr>
<tr>
<td>Design Yield Strength</td>
<td>33 ksi (228 MPa)</td>
<td>50 ksi (345 MPa)</td>
</tr>
<tr>
<td>Nominal Depth of Joist</td>
<td>8” (203 mm)</td>
<td>12” (305 mm)</td>
</tr>
<tr>
<td>Bearing Width</td>
<td>1½” (38.1 mm)</td>
<td>n/a</td>
</tr>
<tr>
<td>Clip Angle Bearing Stiffener:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>1½&quot;x 1½&quot; (38.1 mm x 38.1 mm)</td>
<td>1½&quot;x 1½&quot; (38.1 mm x 38.1 mm)</td>
</tr>
<tr>
<td>Design Thickness</td>
<td>0.0312&quot; (0.792 mm)</td>
<td>0.0713&quot; (1.811 mm)</td>
</tr>
<tr>
<td>Design Yield Strength</td>
<td>33 ksi (228 MPa)</td>
<td>50 ksi (345 MPa)</td>
</tr>
<tr>
<td>Length</td>
<td>Joist depth minus 3/8&quot; (9.5 mm)</td>
<td>n/a</td>
</tr>
<tr>
<td>Installation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screw Size</td>
<td>No. 8 for angle design thickness less than or equal to 0.0566&quot; (1.438 mm), and No. 10 for thicker angles</td>
<td>n/a</td>
</tr>
<tr>
<td>Fasteners</td>
<td>3 screws connecting legs of bearing stiffener to joist and rim track web, in accordance with Figure B2.5-1</td>
<td>n/a</td>
</tr>
</tbody>
</table>

B2.6 Bracing Design

Bracing members shall be designed either on the basis of discretely braced design or on the basis of continuously braced design, in accordance with the following:

(a) Discretely Braced Design. For discretely braced design, bracing members shall be designed in accordance with Section D3 of AISI S100 [CSA S136].

(b) Continuously Braced Design. For continuously braced design, bracing members shall be designed in accordance with Section D3 of AISI S100 [CSA S136], unless the following requirements, as applicable, are met:

1. The sheathing or deck shall consist of a minimum of 3/8 inch (9.5 mm) wood structural sheathing that complies with DOC PS 1, DOC PS 2, CSA O437 or CSA O325, or steel deck with a minimum profile depth of 9/16 in. (14.3 mm) and a minimum thickness of 0.0269 in. (0.683 mm). The sheathing or deck shall be attached with minimum No. 8 screws at a maximum 12 inches (305 mm) on center.

2. Floor joists and ceiling joists with simple or continuous spans that exceed 8 feet (2.44 m) shall have the tension flanges laterally braced. Each intermediate brace shall be spaced at 8 feet (2.44 m) maximum and shall be designed to resist a required lateral force, $P_L$, determined in accordance with the following:

For uniform loads:

$$P_L = 1.5(m/d) F$$  \hspace{1cm} (Eq. B2.6-1)

where

$m =$ Distance from shear center to mid-plane of web
\[ d = \text{Depth of } C\text{-shape section} \]
\[ F = wa \]
\[ w = \text{Uniform design load [factored load]} \]
\[ a = \text{Distance between center line of braces} \]

For concentrated loads:

If \( x \leq 0.3a \):
\[ P_L = 1.0(m/d) F \]  \hspace{1cm} (Eq. B2.6-2)

If \( 0.3a < x < 1.0a \):
\[ P_L = 1.4(m/d)(1-x/a) F \]  \hspace{1cm} (Eq. B2.6-3)

where
\[ m = \text{Distance from shear center to mid-plane of web} \]
\[ d = \text{Depth of } C\text{-shape section} \]
\[ F = \text{Concentrated design load [factored load]} \]
\[ x = \text{Distance from concentrated load to brace} \]
\[ a = \text{Distance between center line of braces} \]

B2.7 Floor Diaphragm Design

Diaphragms shall be designed in accordance with Section B5.

B3 Wall Framing

The requirements in Section B3 shall be used in conjunction with the requirements in Section B1, as applicable.

B3.1 Scope

Sections B3.2 through B3.5 are applicable to wall systems that utilize cold-formed steel structural members.

B3.2 Wall Stud Design

Wall studs shall be designed in accordance with the requirements of this section.

B3.2.1 Available Axial Strength [Factored Resistance]

The available axial strength [factored resistance] of wall stud shall be the lesser of the available strengths [factored resistance] obtained by Sections B3.2.1.1 and B3.2.1.2.

B3.2.1.1 Yielding, Flexural, Flexural-Torsional and Torsional Buckling

Wall studs shall be designed either on the basis of all steel design or on the basis of sheathing braced design with both ends of the stud connected to restrain rotation about the longitudinal stud axis and horizontal displacement perpendicular to the stud axis, in accordance with the following:

(a) All Steel Design. For all steel design of wall studs in compression, Sections C4.1 and D4.1 of AISI S100 [CSA S136] shall define the available axial strength [factored resistance]. The effective length, \( KL \), shall be determined by rational engineering analysis or testing, or in the absence of such analysis or tests, \( K_x \), \( K_y \), and \( K_t \) shall be taken as unity. The unbraced length with respect to the major axis, \( L_{Kx} \), shall be taken as the distance between end supports of the member, while unbraced lengths \( L_y \) and \( L_t \) shall be taken as the distance between center line of braces.
(b) Sheathing Braced Design. For sheathing braced design of wall studs in compression, the available axial strength [factored resistance] shall be determined in accordance with Section C4.1 of AISI S100 [CSA S136]. The unbraced length with respect to the major axis, Lx, shall be taken as the distance between end supports of the member. The unbraced length with respect to the minor axis, Ly, and the unbraced length for torsion, Lt, shall be taken as twice the distance between sheathing connectors. The buckling coefficients Kx, Ky, and Kt shall be taken as unity.

To prevent failure of the sheathing-to-wall stud connection, where identical gypsum sheathing is attached to both sides of the wall stud with screws spaced at a maximum of 12 inches (305 mm) on center, the maximum axial nominal load [specified load] in the wall stud shall be limited to the values given in Table B3.2-1.

<table>
<thead>
<tr>
<th>Gypsum Sheathing</th>
<th>Screw Size</th>
<th>Maximum Nominal [Specified] Stud Axial Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 inch (12.7 mm)</td>
<td>No. 6</td>
<td>5.8 kips (25.8 kN)</td>
</tr>
<tr>
<td>1/2 inch (12.7 mm)</td>
<td>No. 8</td>
<td>6.7 kips (29.8 kN)</td>
</tr>
<tr>
<td>5/8 inch (15.9 mm)</td>
<td>No. 6</td>
<td>6.8 kips (30.2 kN)</td>
</tr>
<tr>
<td>5/8 inch (15.9 mm)</td>
<td>No. 8</td>
<td>7.8 kips (34.7 kN)</td>
</tr>
</tbody>
</table>

B3.2.1.2 Distortional Buckling

Wall studs shall be designed either on the basis of all steel design or on the basis of sheathing braced design, in accordance with the following:

(a) All Steel Design. For all steel design, compression shall be evaluated in accordance with Section C4.2 of AISI S100 [CSA S136]. If the discrete bracing restricts rotation of both flanges about the web/flange juncture, the distance between braces shall be used as Lm when applying AISI S100 [CSA S136].

(b) Sheathing Braced Design. For sheathing braced design, compression shall be evaluated in accordance with Section C4.2 of AISI S100 [CSA S136]. The rotational stiffness, kφ, provided by the sheathing or deck to the wall stud shall be determined in accordance with Appendix 1.

B3.2.2 Bending

The available flexural strength [factored resistance] of wall stud shall be the lesser of the strengths [resistance] obtained by Sections B3.2.2.1 and B3.2.2.2.

B3.2.2.1 Lateral-Torsional Buckling

Wall studs shall be designed either on the basis of all steel design or on the basis of sheathing braced design, in accordance with the following:

(a) All Steel Design. For all steel design, Section C3.1.2 of AISI S100 [CSA S136] shall define the available flexural strength [factored resistance].

(b) Sheathing Braced Design. For sheathing braced design, and assuming full rotational restraint provided by the sheathing, Section C3.1.1 of AISI S100 [CSA S136] shall...
define the available flexural strength [factored resistance].

**B3.2.2.2 Distortional Buckling**

Wall studs shall be designed either on the basis of all steel design or on the basis of sheathing braced design, in accordance with the following:

(a) All Steel Design. For all steel design, flexure shall be evaluated in accordance with Section C3.1.4 of AISI S100 [CSA S136]. If the discrete bracing restricts rotation of the compression flange about the web/flange juncture, the distance between braces shall be used as $L_m$ when applying AISI S100 [CSA S136].

(b) Sheathing Braced Design. For sheathing braced design, flexure shall be evaluated in accordance with Section C3.1.4 of AISI S100 [CSA S136]. The rotational stiffness, $k_{\phi}$, provided by the sheathing or deck to the compression flange of the wall stud shall be determined in accordance with Appendix 1.

**B3.2.3 Shear**

The available shear strength [factored resistance] shall be determined in accordance with Section C3.2 of AISI S100 [CSA S136].

**B3.2.4 Axial Load and Bending**

The combination of axial load and bending shall be evaluated in accordance with Section C5 of AISI S100 [CSA S136].

**B3.2.5 Web Crippling**

The available web crippling strength [factored resistance] shall be determined in accordance with Section C3.4 of AISI S100 [CSA S136], or shall be determined in accordance with Section B3.2.5.1 for C-section stud-to-track connections and Section B3.2.5.2 for C-section stud-to-deflection track connections.

**B3.2.5.1 Stud-to-Track Connection for C-Section Studs**

The available web crippling strength [factored resistance] of C-Section stud-to-track connections are permitted to be determined in accordance with Items (a) to (c), as applicable:

(a) For single curtain wall studs where both stud flanges are connected to the track flanges, the nominal strength [resistance], $P_{nst}$, shall be determined in accordance with Eq. B3.2.5.1-1. For members consisting of two studs, $P_{nst}$ is the sum of the individual stud web capacities with the stud design thickness, $t$, taken as the thickness of one web.

$$
P_{nst} = C t^2 F_y \left( 1 - C_R \frac{R}{t} \right) \left( 1 + C_N \frac{N}{t} \right) \left( 1 - C_h \frac{h}{t} \right)
$$

(Eq. B3.2.5.1-1)

where

- $C$ = Web crippling coefficient listed in Table B3.2.5.1-1
- $C_R$ = Inside bend radius coefficient
  = 0.19
- $C_N$ = Bearing length coefficient
  = 0.74

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\( C_h \) = Web slenderness coefficient
\[ = 0.019 \]

\( R \) = Stud inside bend radius

\( N \) = Stud bearing length
\[ = 1.25 \text{ inch (32 mm)} \]

\( h \) = Depth of flat portion of stud web measured along plane of web

\( t \) = Stud design thickness

The available strength \( [\text{factored resistance}] \) shall be determined using the safety factor \( (\Omega) \) or the resistance factor \( (\phi) \) as follows:

\[ \Omega = 1.70 \text{ for ASD for single stud interior configuration} \]
\[ = 1.90 \text{ for ASD for all other configurations listed in Table B3.2.5.1-1} \]

\[ \phi = 0.90 \text{ for LRFD for single stud interior configuration} \]
\[ = 0.85 \text{ for LRFD for all other configurations listed in Table B3.2.5.1-1} \]
\[ = 0.75 \text{ for LSD for single stud interior configuration} \]
\[ = 0.70 \text{ for LSD for all other configurations listed in Table B3.2.5.1-1} \]

Equation B3.2.5.1-1 shall be valid for the range of parameters listed in Table B3.2.5.1-2.

### Table B3.2.5.1-1
Web Crippling Coefficients

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Location</th>
<th>Web Crippling Coefficient, ( C )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single stud</td>
<td>Interior</td>
<td>3.70</td>
</tr>
<tr>
<td>Single stud with reinforcing lips facing opening</td>
<td>At a wall opening</td>
<td>2.78</td>
</tr>
<tr>
<td>Single stud with stud web facing opening</td>
<td>At a wall opening</td>
<td>1.85</td>
</tr>
<tr>
<td>Toe-to-toe double studs</td>
<td>Interior</td>
<td>7.40</td>
</tr>
<tr>
<td>Toe-to-toe double studs</td>
<td>At an opening</td>
<td>5.55</td>
</tr>
<tr>
<td>Back-to-back double studs</td>
<td>Interior</td>
<td>7.40</td>
</tr>
<tr>
<td>Back-to-back double studs</td>
<td>At an opening</td>
<td>7.40</td>
</tr>
</tbody>
</table>
Table B3.2.5.1-2
Parameters for Equation B3.2.5.1-1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Screw Size</strong></td>
<td>No. 8 for 0.0451 in. (1.146 mm) and thinner stud design thickness</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>No. 10 for 0.0452 to 0.0566 in. (1.147 to 1.438 mm) stud design thickness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No. 12 for 0.0567 in. (1.439 mm) and thicker stud design thickness</td>
<td></td>
</tr>
<tr>
<td><strong>Stud Section:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Design Thickness</strong></td>
<td>0.0346 inch (0.88 mm)</td>
<td>0.0770 inch (1.96 mm)</td>
</tr>
<tr>
<td><strong>Design Yield Strength</strong></td>
<td>33 ksi (228 MPa)</td>
<td>50 ksi (345 MPa)</td>
</tr>
<tr>
<td><strong>Nominal Depth</strong></td>
<td>3.50 inch (88.9 mm)</td>
<td>6.0 inch (152.4 mm)</td>
</tr>
<tr>
<td><strong>Track Section:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Design Thickness</strong></td>
<td>0.0346 inch (0.88 mm)</td>
<td>0.0770 inch (1.96 mm)</td>
</tr>
<tr>
<td><strong>Design Yield Strength</strong></td>
<td>33 ksi (228 MPa)</td>
<td>50 ksi (345 MPa)</td>
</tr>
<tr>
<td><strong>Nominal Depth</strong></td>
<td>3.50 inch (88.9 mm)</td>
<td>6.0 inch (152.4 mm)</td>
</tr>
<tr>
<td><strong>Nominal Flange Width</strong></td>
<td>1.25 inch (31.8 mm)</td>
<td>2.375 inch (60.3 mm)</td>
</tr>
</tbody>
</table>

(b) For single curtain wall studs that are not adjacent to wall openings and where both stud flanges are connected to the track flanges and the track thickness is less than the stud thickness, the nominal strength [resistance], $P_{nst}$, shall be the lesser value determined in accordance with Equation B3.2.5.1-1 or B3.2.5.1-2.

$$P_{nst} = 0.6 t_t w_{st} F_{ut} \quad (Eq. B3.2.5.1-2)$$

where:
- $t_t$ = Track design thickness
- $w_{st} = 20 t_t + 0.56 \alpha$
- $\alpha$ = Coefficient for conversion of units
  - $= 1.0$ when $t_t$ is in inches
  - $= 25.4$ when $t_t$ is in mm
- $F_{ut}$ = Tensile strength of the track
- $P_{nst}$ = Nominal strength [resistance] for the stud-to-track connection when subjected to transverse loads

The available strength [factored resistance] shall be determined using the safety factor ($\Omega$) or the resistance factor ($\phi$) as follows:
- $\Omega = 1.70$ for ASD
- $\phi = 0.90$ for LRFD
- $\phi = 0.80$ for LSD

Equation B3.2.5.1-2 shall be valid for the range of parameters listed in Table B3.2.5.1-3.
### Table B3.2.5.1-3
Parameters for Equation B3.2.5.1-2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screw Size</td>
<td>No. 8</td>
<td>n/a</td>
</tr>
<tr>
<td>Stud Section:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Thickness</td>
<td>0.0346 inch (0.88 mm)</td>
<td>0.0770 inch (1.96 mm)</td>
</tr>
<tr>
<td>Design Yield Strength</td>
<td>33 ksi (228 MPa)</td>
<td>50 ksi (345 MPa)</td>
</tr>
<tr>
<td>Nominal Depth</td>
<td>3.50 inch (88.9 mm)</td>
<td>6.0 inch (152.4 mm)</td>
</tr>
<tr>
<td>Track Section:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Thickness</td>
<td>0.0346 inch (0.88 mm)</td>
<td>0.0770 inch (1.96 mm)</td>
</tr>
<tr>
<td>Design Yield Strength</td>
<td>33 ksi (228 MPa)</td>
<td>50 ksi (345 MPa)</td>
</tr>
<tr>
<td>Nominal Depth</td>
<td>3.50 inch (88.9 mm)</td>
<td>6.0 inch (152.4 mm)</td>
</tr>
<tr>
<td>Nominal Flange Width</td>
<td>1.25 inch (31.8 mm)</td>
<td>2.375 inch (60.3 mm)</td>
</tr>
</tbody>
</table>

(c) For curtain wall jamb studs made up of two studs connected back-to-back where both stud flanges are connected to the track flanges and the track thickness is the same as the stud thickness, the nominal strength [resistance], $P_{nst}$, is the lesser value determined in accordance with Equation B3.2.5.1-1 or B3.2.5.1-3.

$$P_{nst} = 15.2 \, t_t^2 \, F_{ut} \quad (Eq. \text{B3.2.5.1-3})$$

where

- $t_t = \text{Track design thickness}$
- $F_{ut} = \text{Tensile strength of the track}$

The available strength [factored resistance] shall be determined using the safety factor ($\Omega$) or the resistance factor ($\phi$) as follows:

- $\Omega = 2.10$ for ASD
- $\phi = 0.75$ for LRFD
- $\phi = 0.65$ for LSD

Equation B3.2.5.1-3 shall be valid for the range of parameters listed in Table B3.2.5.1-4.

### Table B3.2.5.1-4
Parameters for Equation B3.2.5.1-3

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screw Size</td>
<td>No. 10</td>
<td>n/a</td>
</tr>
<tr>
<td>Stud Section:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Thickness</td>
<td>0.0346 inch (0.88 mm)</td>
<td>0.0770 inch (1.96 mm)</td>
</tr>
<tr>
<td>Design Yield Strength</td>
<td>33 ksi (228 MPa)</td>
<td>50 ksi (345 MPa)</td>
</tr>
<tr>
<td>Nominal Depth</td>
<td>3.50 inch (88.9 mm)</td>
<td>6.0 inch (152.4 mm)</td>
</tr>
<tr>
<td>Track Section:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Thickness</td>
<td>0.0346 inch (0.88 mm)</td>
<td>0.0770 inch (1.96 mm)</td>
</tr>
<tr>
<td>Design Yield Strength</td>
<td>33 ksi (228 MPa)</td>
<td>50 ksi (345 MPa)</td>
</tr>
<tr>
<td>Nominal Depth</td>
<td>3.50 inch (88.9 mm)</td>
<td>6.0 inch (152.4 mm)</td>
</tr>
<tr>
<td>Nominal Flange Width</td>
<td>1.25 inch (31.8 mm)</td>
<td>1.25 inch (31.8 mm)</td>
</tr>
</tbody>
</table>
(d) For curtain wall studs that are not adjacent to wall openings and do not have both stud flanges connected to the track flanges and the track thickness is greater than or equal to the stud thickness, nominal strength [resistance], \( P_{nst} \) shall equal \( P_n \) along with \( \Omega \) and \( \phi \), as determined by Section C3.4.1 of AISI S100 [CSA S136]. For two studs connected back-to-back, the two members shall be considered individually as single web members.

(e) For curtain wall studs that are adjacent to wall openings and do not have both stud flanges connected to the track flanges and the track thickness is greater than or equal to the stud thickness, nominal strength [resistance], \( P_{nst} \) shall equal 0.5\( P_n \) along with \( \Omega \) and \( \phi \), as determined by Section C3.4.1 of AISI S100 [CSA S136]. For two studs connected back-to-back, the two members shall be considered individually as single web members.

**B3.2.5.2 Deflection Track Connection for C-Section Studs**

**B3.2.5.2.1** For curtain wall studs used in deflection track connections, the nominal web crippling strength [resistance], \( P_{nst} \) and the \( \Omega \) and \( \phi \) factors shall be determined by Section C3.4.1 of AISI S100 [CSA S136]. The bearing length used in these calculations shall not exceed the minimum engagement between the stud and the track or 1 inch (25.4 mm).

**B3.2.5.2.2** The nominal strength [resistance] of a single deflection track subjected to transverse loads and connected to its support at a fastener spacing not greater than the stud spacing shall be determined in accordance with Eq. B3.2.5.2-1.

\[
P_{ndt} = \frac{w_{dt}t^2_{t}F_y}{4e}
\]

(Eq. B3.2.5.2-1)

where

\( w_{dt} = \) Effective track length
\( = 0.11(\alpha^2)(e^{0.5}/t_{t}^{1.5}) + 5.5\alpha \leq S \)  

(Eq. B3.2.5.2-2)

\( S = \) Center-to-center spacing of studs
\( t_{t} = \) Track design thickness
\( F_y = \) Design yield strength of track material
\( e = \) Design end or slip gap (distance between stud web at end of stud and track web)
\( \alpha = \) Coefficient for conversion of units

\( = 1.0 \) when \( e, t_{t} \) and \( S \) are in inches
\( = 25.4 \) when \( e, t_{t} \) and \( S \) are in mm

The available strength [factored resistance] shall be determined using the safety factor (\( \Omega \)) or the resistance factor (\( \phi \)) as follows:

\( \Omega = 2.80 \) for ASD
\( \phi = 0.55 \) for LRFD
\( = 0.45 \) for LSD

Equation B3.2.5.2-1 shall be valid for the range of parameters listed in Table B3.2.5.2-1. Additionally, the horizontal distance from the web side of the stud to the terminating end of the track shall not be less than one-half the effective track length \( w_{dt} \).
Table B3.2.5.2-1
Parameters for Equation B3.2.5.2-1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screw Size</td>
<td>No. 10</td>
<td>n/a</td>
</tr>
<tr>
<td>Stud Section:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Thickness</td>
<td>0.0451 inch (1.14 mm)</td>
<td>0.0713 inch (1.81 mm)</td>
</tr>
<tr>
<td>Design Yield Strength</td>
<td>33 ksi (228 MPa)</td>
<td>50 ksi (345 MPa)</td>
</tr>
<tr>
<td>Nominal Depth</td>
<td>3.50 inch (88.9 mm)</td>
<td>6.0 inch (152.4 mm)</td>
</tr>
<tr>
<td>Nominal Flange Width</td>
<td>1.625 inch (41.3 mm)</td>
<td>2.50 inch (63.5 mm)</td>
</tr>
<tr>
<td>Stud Spacing</td>
<td>12 inch (305 mm)</td>
<td>24 inch (610 mm)</td>
</tr>
<tr>
<td>Stud Bearing Length</td>
<td>¾ inch (19.1 mm)</td>
<td>n/a</td>
</tr>
<tr>
<td>Track Section:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Thickness</td>
<td>0.0451 inch (1.14 mm)</td>
<td>0.0713 inch (1.81 mm)</td>
</tr>
<tr>
<td>Design Yield Strength</td>
<td>33 ksi (228 MPa)</td>
<td>50 ksi (345 MPa)</td>
</tr>
<tr>
<td>Nominal Depth</td>
<td>3.50 inch (88.9 mm)</td>
<td>6.0 inch (152.4 mm)</td>
</tr>
<tr>
<td>Nominal Flange Width</td>
<td>2.00 inch (50.8 mm)</td>
<td>3.00 inch (76.3 mm)</td>
</tr>
</tbody>
</table>

B3.3 Header Design

B3.3.1 Back-to-Back Headers

The requirements of this section shall be limited to back-to-back header beams that are installed using cold-formed steel C-shape sections in accordance with Section C3.4.4.

B3.3.1.1 Bending

Bending shall be evaluated in accordance with Section C3.1.1 of AISI S100 [CSA S136].

B3.3.1.2 Shear

Shear shall be evaluated in accordance with Section C3.2 of AISI S100 [CSA S136].

B3.3.1.3 Web Crippling

Web crippling shall be evaluated in accordance with Section C3.4 of AISI S100 [CSA S136]. For back-to-back header beams, the coefficients for built-up sections in Table C3.4.1-1 of AISI S100 [CSA S136] shall be used.

B3.3.1.4 Bending and Shear

The combination of bending and shear shall be evaluated in accordance with Section C3.3 of AISI S100 [CSA S136].

B3.3.1.5 Bending and Web Crippling

Webs of back-to-back header beams subjected to a combination of bending and web crippling shall be designed in accordance with Section C3.5 of AISI S100 [CSA S136]. For back-to-back header beams, AISI S100 [CSA S360] Sections C3.5.1 (b) for ASD and C3.5.2 (b) for LRFD and LSD shall be used.
B3.3.2 Box Headers

The requirements of this section shall be limited to box header beams that are installed using cold-formed steel C-shape sections in accordance with Section C3.4.4.

B3.3.2.1 Bending

Bending shall be evaluated in accordance with Section C3.1.1 of AISI S100 [CSA S136].

B3.3.2.2 Shear

Shear shall be evaluated in accordance with Section C3.2 of AISI S100 [CSA S136].

B3.3.2.3 Web Crippling

Web crippling shall be evaluated in accordance with Section C3.4 of AISI S100 [CSA S136]. For box header beams, the equations for shapes having single webs shall be used. The nominal web crippling strength [resistance], \( P_{n} \), for an interior one-flange loading condition, with the applicable \( \Omega \) or \( \phi \) factor specified below, is permitted to be multiplied by \( \alpha \), where \( \alpha \) accounts for the increased strength due to the track and is specified as follows:

\[ \alpha = \text{Parameter determined in accordance with equation B3.3.2.3-1 or B3.3.2.3-2} \]

The available strength [factored resistance] shall be determined using the safety factor (\( \Omega \)) or the resistance factor (\( \phi \)) as follows:

\[ \Omega = 1.80 \text{ for ASD} \]
\[ \phi = 0.85 \text{ for LRFD} \]
\[ \phi = 0.80 \text{ for LSD} \]

Where the track section design thickness \( \geq 0.0346 \text{ in. (0.879 mm)} \), the track flange width \( \geq 1 \text{ in. (25.4 mm)} \), the C-shape section depth \( \leq 12 \text{ in. (305 mm)} \) and the C-shape section design thickness \( \geq 0.0346 \text{ in. (0.879 mm)} \):

\[ \alpha = 2.3 \frac{t_{t}}{t_{c}} \geq 1.0 \quad (Eq. \ B3.3.2.3-1) \]

where

\[ t_{t} = 0.0346 \text{ in. (0.879 mm)} \]
\[ t_{c} = \text{Design thickness of the C-shape section} \]

Where the limits of Equation B3.3.2.3-1 are not met:

\[ \alpha = 1.0 \quad (Eq. \ B3.3.2.3-2) \]

B3.3.2.4 Bending and Shear

The combination of bending and shear shall be evaluated in accordance with Section C3.3 of AISI S100 [CSA S136].

B3.3.2.5 Bending and Web Crippling

Webs of box header beams subjected to a combination of bending and web crippling shall be determined in accordance with either Section C3.5 of AISI S100 [CSA S136] or the following equations:
(a) For ASD:
\[
\frac{P}{P_n} + \frac{M}{M_n} \leq \frac{1.5}{\Omega}
\]  
(Eq. B3.3.2.5-1)

where

- \(P\) = Required web crippling strength
- \(M\) = Required flexural strength
- \(P_n\) = Nominal web crippling strength determined in accordance with Section B3.3.2.3
- \(M_n\) = Nominal flexural strength defined in Section C3.1 of AISI S100 [CSA S136]

The available strength [factored resistance] shall be determined using the safety factor (\(\Omega\)) as follows:

- \(\Omega = 1.85\)

(b) For LRFD and LSD:
\[
\frac{P_u}{P_n} + \frac{M_u}{M_n} \leq 1.5\phi
\]  
(Eq. B3.3.2.5-2)

where

- \(P_u\) = Required web crippling strength [compression force due to factored loads]
- \(M_u\) = Required flexural strength [moment due to factored loads]
- \(P_n\) = Nominal web crippling strength [resistance] computed by Section B3.3.2.3
- \(M_n\) = Nominal flexural strength [resistance] defined in Section C3.1 of AISI S100 [CSA S136]

The available strength [factored resistance] shall be determined using the resistance factor (\(\phi\)) as follows:

- \(\phi = 0.85\) for LRFD
- \(\phi = 0.80\) for LSD

### B3.3.3 Double L-Headers

The requirements of this section shall be limited to double L-headers that are installed using two cold-formed steel angles in accordance with Section C3.4.5 and meet all of the following conditions:

(a) Minimum top flange width = 1.5 inches (38.1 mm)
(b) Maximum vertical leg dimension = 10 inches (254 mm)
(c) Minimum base steel thickness = 0.033 inches (0.838 mm)
(d) Maximum design thickness = 0.0713 inches (1.829 mm)
(e) Minimum design yield strength, \(F_y = 33\) ksi (230 MPa)
(f) Maximum design yield strength, \(F_y = 50\) ksi (345 MPa)
(g) Cripple stud located at all load points
(h) Minimum bearing length 1.5 inches (38.1 mm) at load points
(i) Minimum wall width = 3.5 inches (88.9 mm)
(j) Maximum span = 16 ft.-0 in. (4.88 m)
B3.3.3.1 Bending

The available flexural strength [factored resistance] of double L-headers shall be determined in accordance with this section.

B3.3.3.1.1 Gravity Loading

The gravity nominal flexural strength [moment resistance], $M_{ng}$, shall be determined as follows:

$$M_{ng} = \text{Sec} \cdot F_y \quad \text{when } L/L_h \geq 10 \quad (\text{Eq. B3.3.3.1.1-1})$$

$$= 0.9 \cdot \text{Sec} \cdot F_y \quad \text{when } L/L_h < 10 \text{ and } L_h > 8 \text{ in. (203 mm)} \quad (\text{Eq. B3.3.3.1.1-2})$$

The available strength [factored resistance] shall be determined using the safety factor ($\Omega$) or the resistance factor ($\phi$) as follows:

For $L_h \leq 8$ in. (203 mm):

$$\Omega = 1.67 \quad (\text{ASD})$$
$$\phi = 0.90 \quad (\text{LRFD})$$
$$= 0.85 \quad (\text{LSD})$$

For $L_h > 8$ in. (203 mm):

$$\Omega = 2.25 \quad (\text{ASD})$$
$$\phi = 0.70 \quad (\text{LRFD})$$
$$= 0.65 \quad (\text{LSD})$$

where

$F_y = \text{Yield strength used for design}$

$\text{Sec} = \text{Elastic section modulus of the effective section calculated at } f = F_y \text{ in the extreme compression fibers}$

$L = \text{Span length}$

$L_h = \text{Vertical leg dimension of angle}$

B3.3.3.1.2 Uplift Loading

The nominal uplift flexural strength [moment resistance], $M_{nu}$, shall be determined as follows:

$$M_{nu} = R \cdot M_{ng} \quad (\text{Eq. B3.3.3.1.2-1})$$

The available strength [factored resistance] shall be determined using the safety factor ($\Omega$) or the resistance factor ($\phi$) as follows:

$$\Omega = 2.0 \quad (\text{ASD})$$
$$\phi = 0.80 \quad (\text{LRFD})$$
$$= 0.75 \quad (\text{LSD})$$

where

$M_{ng} = \text{Gravity nominal flexural strength [moment resistance]}$ determined by Eq. B3.3.3.1.2-1

$R = \text{Uplift factor}$

$= 0.25 \text{ for } L_h/t \leq 150$

$= 0.20 \text{ for } L_h/t \geq 170$

$= \text{For } 150 < L_h/t < 170 \text{ use linear interpolation}$

$L_h = \text{Vertical leg dimension of the angle}$

$t = \text{Design thickness}$
B3.3.3.2 Shear

Shear need not be evaluated for the design of double L-header beams that are fabricated and installed in accordance with this Standard.

B3.3.3.3 Web Crippling

Web crippling need not be evaluated for the design of double L-header beams that are fabricated and installed in accordance with this Standard.

B3.3.3.4 Bending and Shear

The combination of bending and shear need not be evaluated for the design of double L-header beams fabricated and installed in accordance with this Standard.

B3.3.3.5 Bending and Web Crippling

The combination of bending and web crippling need not be evaluated for the design of double L-header beams fabricated and installed in accordance with this Standard.

B3.3.4 Single L-Headers

The requirements of this section shall be limited to single L-headers that are installed using one cold-formed steel angle in accordance with Section C3.4.5 and meet all of the following conditions:

(a) Minimum top flange width = 1.5 inches (38.1 mm)
(b) Maximum vertical leg dimension = 8 inches (203 mm)
(c) Minimum base steel thickness = 0.033 inches (0.838 mm)
(d) Maximum design thickness = 0.0566 inches (1.448 mm)
(e) Minimum design yield strength, $F_y = 33$ ksi (230 MPa)
(f) Maximum design yield strength, $F_y = 50$ ksi (345 MPa)
(g) Cripple stud located at all load points
(h) Minimum bearing length 1.5 inches (38.1 mm) at load points
(i) Minimum wall width = 3.5 inches (88.9 mm)
(j) Maximum span = 4'-0" (1.219 m)

B3.3.4.1 Bending

The available flexural strength [factored resistance] of single L-headers shall be determined in accordance with this section.

B3.3.4.1.1 Gravity Loading

The gravity nominal flexural strength [resistance], $M_{ng}$, shall be determined as follows:

$M_{ng} = S_{ec} F_y$ when $L_h \leq 6$ in. (152 mm)  \hspace{1cm} (Eq. B3.3.4.1.1-1)

$= 0.9 S_{ec} F_y$ when 6 in. (152 mm) < $L_h \leq 8$ in. (203 mm) \hspace{1cm} (Eq. B3.3.4.1.1-1)

The available strength [factored resistance] shall be determined using the safety factor ($\Omega$) or the resistance factor ($\phi$) as follows:

$\Omega = 1.67$ (ASD)
\[ \phi = 0.90 \ (LRFD) = 0.85 \ (LSD) \]

where

- \( F_y \) = Yield strength used for design
- \( S_{ec} \) = Elastic section modulus of the effective section calculated at \( f = F_y \) in the extreme compression fibers

**B3.3.4.1.2 Uplift Loading**

[Reserved]

**B3.3.4.2 Shear**

Shear need not be evaluated for the design of single L-header beams that are fabricated and installed in accordance with this Standard.

**B3.3.4.3 Web Crippling**

Web crippling need not be evaluated for the design of single L-header beams that are fabricated and installed in accordance with this Standard.

**B3.3.4.4 Bending and Shear**

The combination of bending and shear need not be evaluated for the design of single L-header beams fabricated and installed in accordance with this Standard.

**B3.3.4.5 Bending and Web Crippling**

The combination of bending and web crippling need not be evaluated for the design of single L-header beams fabricated and installed in accordance with this Standard.

**B3.3.5 Inverted L-Header Assemblies**

**B3.3.5.1** The requirements of this section shall be limited to inverted double or single L-header assemblies satisfying the limitations specified in Section B3.3.3 for double L-headers and B3.3.4 for single L-headers, respectively. The installation of inverted L-header assemblies shall be in accordance with C3.4.6.

**B3.3.5.2** For double inverted L-header assemblies, the nominal flexural strength [moment resistance] of the combined L-header assembly (i.e., double L-headers plus inverted double L-headers) shall be determined by summing the gravity and uplift nominal flexural strengths [moment resistances] as determined in accordance with Section B3.3.3.1.

**B3.3.5.3** For single inverted L-header assemblies, the nominal flexural strength [moment resistance] of the combined L-header assembly (i.e., a single L-header plus an inverted single L-header) shall be based on the gravity nominal flexural strength [moment resistance] as determined in accordance with Section B3.3.4.1.

**B3.3.5.4** Shear, web crippling, bending and shear, and bending and web crippling need not be evaluated for the design of inverted L-headers fabricated and installed in accordance with this Standard.
B3.4  Bracing

B3.4.1  Intermediate Brace Design

B3.4.1.1 For bending members, each intermediate brace shall be designed in accordance with Section D3.2.1 of AISI S100 [CSA S136].

B3.4.1.2 For axial loaded members, each intermediate brace shall be designed for 2% of the design compression force in the member.

B3.4.1.3 For combined bending and axial loads, each intermediate brace shall be designed for the combined brace force determined in accordance with Section D3.2.1 of AISI S100 [CSA S136] and 2% of the design compression force in the member.

B3.5  Serviceability

Serviceability limits shall be chosen based on the intended function of the wall system, and shall be evaluated using load and load combinations in accordance with Section B1.1.

B4  Roof Framing

The requirements in Section B4 shall be used in conjunction with the requirements in Section B1, as applicable.

B4.1  Scope

Sections B4.2 through B4.6 are applicable to roof systems that utilize cold-formed steel structural members.

B4.2  Roof Rafter Design

Roof rafters shall be designed in accordance with the requirements of this section.

B4.2.1  Tension

Tension shall be evaluated in accordance with Section C2 of AISI S100 [CSA S136].

B4.2.2  Compression

The available compression strength [resistance] of roof rafters shall be the lesser values obtained from Sections B4.2.2.1 and B4.2.2.2.

B4.2.2.1  Yielding, Flexural, Flexural-Torsional and Torsional Buckling

Compression shall be evaluated in accordance with Section C4.1 of AISI S100 [CSA S136].

B4.2.2.2  Distortional Buckling

Roof rafters shall be designed either on the basis of discretely braced design or on the basis of continuously braced design, in accordance with the following:

(a) Discretely Braced Design. For discretely braced design, compression shall be evaluated in accordance with Section C4.2 of AISI S100 [CSA S136]. If the discrete bracing restricts rotation of the compression flange about the web/flange juncture, the distance between braces shall be used as L_m when applying AISI S100 [CSA S136].

(b) Continuously Braced Design. For continuously braced design, compression shall be evaluated in accordance with Section C4.2 of AISI S100 [CSA S136]. The rotational
stiffness, $k_\phi$, provided by the sheathing or deck to the roof rafter shall be determined in accordance with Appendix 1.

**B4.2.3 Bending**

The available flexural strength [resistance] of roof rafters shall be the lesser values obtained from Sections B4.2.3.1 and B4.2.3.2.

**B4.2.3.1 Lateral-Torsional Buckling**

Roof rafters shall be designed either on the basis of discretely braced design or on the basis of continuously braced design, in accordance with the following:

(a) Discretely Braced Design. For discretely braced design, flexure shall be evaluated in accordance with Section C3.1.2 of AISI S100 [CSA S136].

(b) Continuously Braced Design. For continuously braced design, where structural sheathing or steel deck is attached to the compression flange of the roof rafter in accordance with Section B4.5(1) and the tension flange is braced in accordance with Section B4.5(2), flexure for gravity loading shall be evaluated by using Section C3.1.1 of AISI S100 [CSA S136] and flexure for uplift loading shall be evaluated in accordance with Sections C3.1.2 and D6.1.1 of AISI S100 [CSA S136]. Where structural sheathing or steel deck is attached to both flanges of the roof rafter in accordance with Section B4.5(1), flexure for gravity or uplift loading shall be evaluated in accordance with Section C3.1.1 of AISI S100 [CSA S136].

**B4.2.3.2 Distortional Buckling**

Roof rafters shall be designed either on the basis of discretely braced design or on the basis of continuously braced design, in accordance with the following:

(a) Discretely Braced Design. For discretely braced design, flexure alone shall be evaluated in accordance with Section C3.1.4 of AISI S100 [CSA S136]. If the discrete bracing restricts rotation of the compression flange about the web/flange juncture, the distance between braces shall be used as $L_m$ when applying AISI S100 [CSA S136].

(b) Continuously Braced Design. For continuously braced design, flexure shall be evaluated in accordance with Section C3.1.4 of AISI S100 [CSA S136]. The rotational stiffness, $k_\phi$, provided by the sheathing or deck to the roof rafter shall be determined in accordance with Appendix 1.

**B4.2.4 Shear**

Shear shall be evaluated in accordance with Section C3.2 of AISI S100 [CSA S136].

**B4.2.5 Web Crippling**

Web crippling shall be evaluated in accordance with Section C3.4 of AISI S100 [CSA S136], unless a bearing stiffener is used in accordance with the requirements of Section B4.4.

**B4.2.6 Axial Load and Bending**

The combination of axial load and bending shall be evaluated in accordance with Section C5 of AISI S100 [CSA S136].
**B4.2.7 Bending and Shear**

The combination of flexure and shear shall be evaluated in accordance with Section C3.3 of AISI S100 [CSA S136].

**B4.2.8 Bending and Web Crippling**

The combination of flexure and web crippling shall be evaluated in accordance with Section C3.5 of AISI S100 [CSA S136], unless a bearing stiffener is used in accordance with the requirements of Section B4.4.

**B4.3 Roof Truss Design**

Roof trusses shall be designed in accordance with Chapter E.

**B4.4 Bearing Stiffeners**

Bearing stiffeners shall be designed in accordance with Section C3.7 of AISI S100 [CSA S136].

**B4.5 Bracing Design**

Bracing members shall be designed in accordance with Section D3 of AISI S100 [CSA S136], unless bracing is provided satisfying the following requirements:

(a) In continuously braced design, the sheathing or deck shall consist of a minimum of 3/8 inch (9.5 mm) wood structural sheathing that complies with DOC PS 1, DOC PS 2, CSA O437 or CSA O325, or steel deck with a minimum profile depth of 9/16 in. (14.3 mm) and a minimum thickness of 0.0269 in. (0.683 mm). The sheathing or deck shall be attached with minimum No. 8 screws at a maximum 12 inches (305 mm) on center.

(b) In continuously braced design, roof rafters with simple or continuous spans that exceed 8 feet (2.44 m) shall have the tension flanges laterally braced. Each intermediate brace shall be spaced at 8 feet (2.44 m) maximum and shall be designed to resist a required lateral force, $P_L$, determined in accordance with the following:

(1) For uniform loads:

$$ P_L = 1.5(m/d) F $$

where

$m$ = Distance from shear center to mid-plane of web

$d$ = Depth of C-shape section

$F = w a$

$w$ = Uniform design load [factored load]

$a$ = Distance between center line of braces

(2) For concentrated loads:

If $x \leq 0.3a$

$$ P_L = 1.0(m/d) F $$

(Eq. B4.5-2)

If $0.3a < x < 1.0a$

$$ P_L = 1.4(m/d)(1-x/a) F $$

(Eq. B4.5-3)

where

$m$ = Distance from shear center to mid-plane of web

$d$ = Depth of C-shape section

$F$ = Concentrated design load [factored load]
x = Distance from concentrated load to brace
a = Distance between center line of braces

B4.6 Roof Diaphragm Design

Diaphragms shall be designed in accordance with Section B5.4.

B5 Lateral Force-Resisting Systems

The requirements in Section B5 shall be used in conjunction with the requirements in Section B1, as applicable.

B5.1 Scope

Sections B5.2 through B5.5 are applicable to buildings that utilize cold-formed steel structural members for lateral force-resisting system framing.

User Note:
See Section A1.3 for applicability of this section to cold-formed steel structural members and connections in seismic force-resisting systems.

B5.2 Shear Wall Design

Shear walls shall be designed as either Type I shear walls or Type II shear walls in accordance with the requirements of this section and shall be installed in accordance with the requirements of Section C3.6.1.

User Note:
See Section A1.3 for applicability of this section to cold-formed steel structural members and connections in seismic force-resisting systems.

B5.2.1 General

Type I shear walls shall be fully sheathed with steel sheet sheathing, wood structural panels, gypsum board panels, or fiberboard panels with hold-downs at each end. Type I shear walls sheathed with steel sheet sheathing or wood structural panels are permitted to have openings where details are provided to account for force transfer around openings. Type I shear walls shall conform to the additional requirements of Sections B5.2.1.1.

Type II shear walls shall be sheathed with steel sheet sheathing or wood structural panels with a Type II shear wall segment at each end. Openings are permitted to occur beyond the ends of the Type II shear wall; however, the width of such openings shall not be included in the length of the Type II shear wall. Type II shear walls shall conform to the additional requirements of Section B5.2.1.2.

B5.2.1.1 Type I Shear Walls

Type I shear walls shall conform to the following requirements:
(a) The height-to-length aspect ratio (h/w) of a Type I shear wall does not exceed the values in Tables B5.2.2.3-1 through B5.2.2.3-4.
(b) The length of a Type I shear wall is not less than 24 inches (610 mm).
(c) The height-to-length aspect ratio (h_p/w_p) of a wall pier in a Type I shear wall with openings is limited to a maximum of 2:1, where the height of a wall pier (h_p) is defined as the height of the opening adjacent to the sheathed wall and the length of a...
wall pier \((w_p)\) is the sheathed length of the wall pier adjacent to the opening.

(d) The length of a wall pier \((w_p)\) in a Type I shear wall with openings is not less than 24 inches (610 mm).

**B5.2.1.2 Type II Shear Walls**

Type II shear walls shall conform to the following requirements:

(a) The height-to-length aspect ratio \((h/w)\) of a Type II shear wall segment does not exceed the values in Tables B5.2.2.3-1 through B5.2.2.3-2.

(b) For a Type II shear wall, the nominal strength \([\text{resistance}]\) for shear, \(V_n\), is based upon a screw spacing of not less than 4 inches (100 mm) on center.

(c) Where horizontal out-of-plane offset irregularities occur in a Type II shear wall, portions of the wall on each side of the offset irregularity are designated as separate Type II shear walls.

(d) Collectors for shear transfer are provided for the full length of the Type II shear wall.

(e) Type II shear walls have uniform top-of-wall and bottom-of-wall elevations.

(f) Type II shear wall height, \(h\), does not exceed 20 feet (6.1 m).

**B5.2.2 Nominal Strength [Resistance]**

**B5.2.2.1 Type I Shear Walls**

The nominal strength \([\text{resistance}]\) for shear, \(V_n\), shall be determined in accordance with the following:

For \(h/w \leq 2\),

\[
V_n = v_n w \tag{Eq. B5.2.2-1}
\]

where

\(h\) = Height of the shear wall, ft. \([\text{m}]\).

\(w\) = Length of the shear wall, ft. \([\text{m}]\).

\(v_n\) = Nominal strength \([\text{resistance}]\) per unit length as specified in Section B5.2.2.3, lbs./ft. \([\text{kN/m}]\).

Where permitted in Tables B5.2.2.3-1, B5.2.2.3-2 and Section B5.2.2.3.2.1, the nominal strength \([\text{resistance}]\) for shear, \(V_n\), for height-to-length aspect ratios \((h/w)\) greater than 2:1, but not exceeding 4:1, shall be determined in accordance with the following:

For \(2 < h/w \leq 4\),

\[
V_n = v_n w \left(\frac{2w}{h}\right) \tag{Eq. B5.2.2-2}
\]

**B5.2.2.2 Type II Shear Walls**

The nominal strength \([\text{resistance}]\) for shear, \(V_n\), shall be determined in accordance with the following:

\[
V_n = C_a v_n \Sigma L_i \tag{Eq. B5.2.2-3}
\]

where

\(C_a\) = Shear resistance adjustment factor from Table B5.2.2.2-1. For intermediate values of opening height ratio and percentages of full-height sheathing, the shear resistance adjustment factors are permitted to be determined by interpolation.
\[ v_n = \text{Nominal strength [resistance]} \text{ per unit length as specified in Section B5.2.2.3, lbs./ft. [kN/m].} \]

\[ \sum L_i = \text{Sum of lengths of Type II shear wall segments, ft. [m].} \]

The percent of full-height sheathing shall be calculated as the sum of lengths (\( \sum L_i \)) of Type II shear wall segments divided by the total length of the Type II shear wall including openings.

The maximum opening height ratio shall be calculated by dividing the maximum opening clear height by the shear wall height, \( h \).

### Table B5.2.2.2-1

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<th>Maximum Opening Height Ratio</th>
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### B5.2.2.3 Nominal Strength [Resistance] per Unit Length

#### B5.2.2.3.1 General Requirements

Type I shear walls and Type II shear walls shall conform to the following requirements:

(a) Wall studs and track are ASTM A1003 Structural Grade 33 (Grade 230) Type H steel for members with a designation thickness of 33 and 43 mils, and ASTM A1003 Structural Grade 50 (Grade 340) Type H steel for members with a designation thickness equal to or greater than 54 mils.

(b) Studs are C-shape members with a minimum flange width of 1-5/8 in. (41.3 mm), minimum web depth of 3-1/2 in. (89 mm) and minimum edge stiffener of 3/8 in. (9.5 mm).

(c) Track has a minimum flange width of 1-1/4 in. (31.8 mm) and a minimum web depth of 3-1/2 in. (89 mm).

(d) Screws for structural members are a minimum No. 8 and are in accordance with ASTM C1513.

(e) Panels less than 12 inches (305 mm) wide are not used.

(f) Maximum stud spacing is 24 inches (610 mm) on center.

(g) All sheathing edges are attached to structural members or panel blocking, unless otherwise specified.

(h) Where used as panel blocking, flat strap is a minimum thickness of 33 mils with a minimum width of 1-1/2 inches (38.1 mm).
B5.2.2.3.2 Steel Sheet Sheathing

The nominal strength [resistance] per unit length for assemblies with steel sheet sheathing and panel blocking shall be as specified in Table B5.2.2.3-1 or determined in accordance with Section B5.2.2.3.2.1.

The nominal strength [resistance] per unit length for unblocked assemblies with panel edges overlapped and attached to each other with screw spacing as required for panel edges in lieu of panel blocking shall be as specified in Table B5.2.2.3-1 multiplied by 0.70.

Tabulated values in Table B5.2.2.3-1 shall be applicable for any load duration.

Systems tabulated in Table B5.2.2.3-1 shall conform to the following additional requirements:

(a) Steel sheet sheathing has a minimum designation thickness as specified in Table B5.2.2.3-1 and complies with ASTM A1003 Structural Grade 33 (Grade 230) Type H.

(b) In Canada, steel sheet sheathing is connected without horizontal joints.

(c) Screws used to attach steel sheets are a minimum No. 8 and are in accordance with ASTM C1513.

B5.2.2.3.2.1 Effective Strip Method

The effective strip method is permitted to be used only in the United States and Mexico. The nominal shear strength [resistance] per unit length for assemblies with steel sheet sheathing shall be determined in accordance with the following:

\[ V_n = \text{minimum}(1.23P_n \cos \alpha, 1.23w_e F_y \cos \alpha) \]  

(Eq. B5.2.2.3.2.1-1)

where

\[ P_n = \text{Nominal shear strength [resistance] of screw connections within the effective strip width, } W_e, \text{ on the steel sheet sheathing} \]

\[ \alpha = \arctan(h/w) \]  

(Eq. B5.2.2.3.2.1-2)

\[ t = \text{Design thickness of steel sheet sheathing} \]

\[ F_y = \text{Yield stress of steel sheet sheathing} \]

\[ w_e = \frac{w_{\text{max}}}{\sin \alpha} \text{ when } \lambda \leq 0.0819 \]  

(Eq. B5.2.2.3.2.1-3)

\[ w_e = \rho w_{\text{max}} \text{ when } \lambda > 0.0819 \]  

(Eq. B5.2.2.3.2.1-4)

where

\[ w_{\text{max}} = \frac{w}{\sin \alpha} \]  

(Eq. B5.2.2.3.2.1-5)

\[ \rho = \frac{1 - 0.55(\lambda - 0.08)^{0.12}}{\lambda^{0.12}} \]  

(Eq. B5.2.2.3.2.1-6)

\[ \lambda = 1.736 \frac{\alpha_1 \alpha_2}{\beta_1 \beta_2 \beta_3 a} \]  

(Eq. B5.2.2.3.2.1-7)

where

\[ \alpha_1 = \frac{F_{\text{ush}}}{45} \text{ (For } F_{\text{ush}} \text{ in ksi)} \]  

(Eq. B5.2.2.3.2.1-8)

\[ \frac{1}{\beta_1} = \frac{F_{\text{ush}}}{310.3} \text{ (For } F_{\text{ush}} \text{ in MPa)} \]  

(Eq. B5.2.2.3.2.1-9)

\[ \alpha_2 = \frac{F_{\text{uf}}}{45} \text{ (For } F_{\text{uf}} \text{ in ksi)} \]  

(Eq. B5.2.2.3.2.1-10)

\[ \frac{1}{\beta_2} = \frac{F_{\text{uf}}}{310.3} \text{ (For } F_{\text{uf}} \text{ in MPa)} \]  

(Eq. B5.2.2.3.2.1-11)

\[ \beta_1 = \frac{t_{\text{sh}}}{0.018} \text{ (For } t_{\text{sh}} \text{ in inches)} \]  

(Eq. B5.2.2.3.2.1-12)
The effective strip method is permitted to be used within the following range of parameters:

(a) Designation thickness of stud, track, and stud blocking: 33 mils (0.838 mm) to 54 mils (1.37 mm).

(b) Designation thickness of steel sheet sheathing: 18 mils (0.457 mm) to 33 mils (0.838 mm).

(c) Screw spacing at panel edges: 2 in. (50.8 mm) to 6 in. (152 mm).

(d) Height-to-width aspect ratio (h:w): 1:1 to 4:1.

(e) Sheathing screw shall be minimum No. 8.

(f) Yield stress of steel sheet sheathing shall not be greater than 50 ksi (345 MPa).

See Section B5.2.2.1 for Type I shear wall height-to-length aspect ratios (h/w) greater than 2:1, but not exceeding 4:1, for additional requirements.

B5.2.2.3.3 Wood Structural Panel Sheathing

The nominal strength [resistance] per unit length for assemblies with wood structural panel sheathing and panel blocking shall be as specified in Table B5.2.2.3-2.

In the United States and Mexico, increases in the nominal strengths [resistances] in Table B5.2.2.3-2, as allowed by other standards, shall not be permitted.

Tabulated values in Table B5.2.2.3-2 shall be applicable for short-term load duration only (wind or seismic loads). In the United States and Mexico, for loads of normal or permanent load duration as defined by the AWC NDS, the values shall be multiplied by 0.63 (normal) or 0.56 (permanent). In Canada, for loads of permanent term load duration (dead), the values shall be multiplied by 0.56. For standard term load duration (snow and occupancy), the values shall be multiplied by 0.80. For other permanent and standard load combinations where the specified dead load is greater than the specified standard term load, the values shall be multiplied by a factor equal to 0.8 - 0.43 log (D/ST) ≥ 0.56, where D = specified dead load and ST = specified standard term load based on snow or occupancy loads acting alone or in combination.

Systems tabulated in Table B5.2.2.3-2 shall conform to the following additional requirements:

(a) Wood structural panel sheathing is manufactured using exterior glue and complies with the following, as applicable:
(1) In the United States and Mexico, DOC PS 1 or PS 2.
(2) In Canada, CSA O121, O151 or CAN/CSA O325.0.

(b) Wood structural panels are applied either parallel to or perpendicular to studs.
(c) Screws used to attach wood structural panels are a minimum No. 8 with a minimum head diameter of 0.285 inch (7.24 mm) and are in accordance with ASTM C1513.

**B5.2.2.3.4 Gypsum Board Panel Sheathing**

The nominal strength [resistance] per unit length for assemblies with gypsum board panel sheathing and panel blocking shall be as specified in Table B5.2.2.3-3.

The nominal strength [resistance] per unit length for unblocked assemblies shall be as specified in Table B5.2.2.3-3 multiplied by 0.35.

Tabulated values in Table B5.2.2.3-3 shall be applicable for short-term load duration only (wind or seismic loads).

Systems tabulated in Table B5.2.2.3-3 shall conform to the following additional requirements:

(a) Gypsum board panels comply with ASTM C1396/C1396M.
(b) Gypsum board panels are applied perpendicular to studs with panel blocking behind the horizontal joint and with stud blocking between the first two end studs, at each end of the wall, or applied vertically with all edges attached to structural members.
(c) Screws used to attach gypsum board are a minimum No. 6 and are in accordance with ASTM C954 or ASTM C1002, as applicable.

**B5.2.2.3.5 Fiberboard Panel Sheathing**

The nominal strength [resistance] per unit length for assemblies with fiberboard panel sheathing and panel blocking shall be as specified in Table B5.2.2.3-4.

Tabulated values in Table B5.2.2.3-4 shall be applicable for short-term load duration only (wind loads only).

Systems tabulated in Table B5.2.2.3-4 shall conform to the following additional requirements:

(a) Fiberboard panels comply with ASTM C208.
(b) Fiberboard is applied perpendicular to studs with panel blocking behind the horizontal joint and with stud blocking between the first two end studs, at each end of the wall, or applied vertically with all edges attached to structural members.
(c) Screws used to attach fiberboard are a minimum No. 8 and are in accordance with ASTM C1513. Head style is selected to provide a flat bearing surface in contact with the sheathing with a head diameter not less than 0.43 inches (10.9 mm). Screws are driven so that their flat bearing surface is flush with the surface of the sheathing.

**B5.2.2.3.6 Combined Systems**

For a Type I shear wall sheathed with the same material and fastener spacing on opposite faces of the same wall, the nominal strength [resistance] of the complete wall based on Tables B5.2.2.3-1 through B5.2.2.3-4 shall be determined by adding the nominal strength [resistance] from the two opposite faces together.

For a Type I shear wall having more than a single sheathing material or fastener
spacing, the nominal strength [resistance] of the complete wall based on Tables B5.2.2.3-1 through B5.2.2.3-4 shall not be permitted to be determined by adding the nominal strength [resistance] from the different individual walls; rather, it shall be determined in accordance with the following:

(a) For a Type I shear wall having more than a single sheathing material or fastener configuration along one face of the same wall line, the nominal strength [resistance] shall be taken either assuming the weaker (lower nominal strength [resistance]) material or fastener configuration exists for the entire length of the wall, or the stronger (higher nominal strength [resistance]) material or fastener configuration exists for its own length, whichever is greater.

(b) In the United States and Mexico, for a Type I shear wall sheathed with 15/32 in. structural 1 sheathing (4-ply) or 7/16 in. rated sheathing (OSB) on one side with screw spacing at 6 inches (150 mm) o.c. edge and 12 inches (300 mm) o.c. field and with 1/2 in. gypsum board on the opposite side with screw spacing at 7 in. (178 mm) o.c. edge and 7 in. (178 mm) o.c. field, the nominal strengths in Table B5.2.2.3-2 are permitted to be increased by 30 percent.

(c) For other cases of a Type I shear wall having more than a single sheathing material or fastener configuration on opposite faces of the wall, the nominal strength [resistance] shall be taken either assuming the weaker material or fastener configuration exists for both faces of the wall, or the stronger material or fastener configuration exists for its own face alone, whichever is greater.
### Table B5.2.2.3-1

Unit Nominal Shear Strength [Resistance] ($v_n$) \(^1,2\)

For Shear Walls with Steel Sheet Sheathing on One Side of Wall

<table>
<thead>
<tr>
<th>Sheathing</th>
<th>Max. Aspect Ratio (h/w)</th>
<th>Fastener Spacing at Panel Edges/Field (inches)</th>
<th>Stud Blocking Required</th>
<th>Designation Thickness of Stud, Track and Blocking (mils)</th>
<th>Required Sheathing Screw Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6/12</td>
<td>4/12</td>
<td>3/12</td>
<td>2/12</td>
</tr>
<tr>
<td>0.018” steel sheet</td>
<td>2:1</td>
<td>485</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.027” steel sheet</td>
<td>4:1^3</td>
<td>-</td>
<td>1,000</td>
<td>1085</td>
<td>1170</td>
</tr>
<tr>
<td>0.027” steel sheet</td>
<td>4:1^3</td>
<td>645</td>
<td>710</td>
<td>780</td>
<td>845</td>
</tr>
<tr>
<td>0.030” steel sheet</td>
<td>4:1^3</td>
<td>795</td>
<td>960</td>
<td>1005</td>
<td>1055</td>
</tr>
<tr>
<td>0.030” steel sheet</td>
<td>4:1^3</td>
<td>910</td>
<td>1015</td>
<td>1040</td>
<td>1070</td>
</tr>
<tr>
<td>0.030” steel sheet</td>
<td>4:1^3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1355</td>
</tr>
<tr>
<td>0.033” steel sheet</td>
<td>4:1^3</td>
<td>1035</td>
<td>1145</td>
<td>1225</td>
<td>1300</td>
</tr>
<tr>
<td>0.033” steel sheet</td>
<td>4:1^3</td>
<td>1055</td>
<td>1170</td>
<td>1235</td>
<td>1305</td>
</tr>
<tr>
<td>0.033” steel sheet</td>
<td>4:1^3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1505</td>
</tr>
<tr>
<td>0.033” steel sheet</td>
<td>4:1^3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1870</td>
</tr>
<tr>
<td>0.033” steel sheet</td>
<td>4:1^3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2085</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sheathing</th>
<th>Max. Aspect Ratio (h/w)</th>
<th>Fastener Spacing at Panel Edges/Field (mm)</th>
<th>Stud Blocking Required</th>
<th>Designation Thickness of Stud, Track and Blocking (mils)</th>
<th>Required Sheathing Screw Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>150/300</td>
<td>100/300</td>
<td>75/300</td>
<td>50/300</td>
</tr>
<tr>
<td>0.46 mm steel sheet</td>
<td>2:1</td>
<td>4.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.46 mm steel sheet</td>
<td>2:1</td>
<td>4.5</td>
<td>6.0</td>
<td>6.8</td>
<td>7.5</td>
</tr>
<tr>
<td>0.46 mm steel sheet</td>
<td>2:1</td>
<td>7.4</td>
<td>9.7</td>
<td>11.6</td>
<td>13.5</td>
</tr>
<tr>
<td>0.68 mm steel sheet</td>
<td>2:1</td>
<td>6.5</td>
<td>7.2</td>
<td>7.9</td>
<td>8.7</td>
</tr>
<tr>
<td>0.76 mm steel sheet</td>
<td>4:1^3</td>
<td>8.9</td>
<td>10.6</td>
<td>11.6</td>
<td>12.5</td>
</tr>
<tr>
<td>0.76 mm steel sheet</td>
<td>2:1</td>
<td>11.7</td>
<td>14.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.76 mm steel sheet</td>
<td>2:1</td>
<td>-</td>
<td>-</td>
<td>19.9</td>
<td>23.3</td>
</tr>
<tr>
<td>0.84 mm steel sheet</td>
<td>4:1^3</td>
<td>10.7</td>
<td>12.0</td>
<td>13.0</td>
<td>14.0</td>
</tr>
</tbody>
</table>

1. For SI: 1” = 25.4 mm, 1 foot = 0.305 m, 1 lb = 4.45 N.
2. See Section B5.2.2.3.6 for requirements for sheathing applied to both sides of wall.
3. See Section B5.2.2.1 for Type I shear wall height-to-length aspect ratios (h/w) greater than 2:1, but not exceeding 4:1.
### Table B5.2.2.3-2
Unit Nominal Shear Strength [Resistance] \((v_n)\) \(^1\,^2\)
For Shear Walls with Wood Structural Panel Sheathing on One Side of Wall

<table>
<thead>
<tr>
<th>Sheathing</th>
<th>Maximum Aspect Ratio ((h/w))</th>
<th>Fastener Spacing at Panel Edges/Field (inches)</th>
<th>Designation Thickness of Stud, Track and Blocking (mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6/12</td>
<td>4/12</td>
</tr>
<tr>
<td>15/32” structural 1 (4-ply)</td>
<td>2:1</td>
<td>1065</td>
<td>1410</td>
</tr>
<tr>
<td>7/16” rated sheathing (OSB)</td>
<td>2:1</td>
<td>910</td>
<td>1410</td>
</tr>
<tr>
<td>7/16” rated sheathing (OSB)</td>
<td>2:1</td>
<td>1020</td>
<td>-</td>
</tr>
<tr>
<td>7/16” rated sheathing (OSB)</td>
<td>4:1 (^3)</td>
<td>-</td>
<td>1025</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sheathing</th>
<th>Maximum Aspect Ratio ((h/w))</th>
<th>Fastener Spacing at Panel Edges/Field (mm)</th>
<th>Designation Thickness of Stud, Track and Blocking (mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>150/300</td>
<td>100/300</td>
</tr>
<tr>
<td>9.5 mm CSP Sheathing</td>
<td>4:1 (^3)</td>
<td>8.5</td>
<td>11.8</td>
</tr>
<tr>
<td>12.5 mm CSP Sheathing</td>
<td>4:1 (^3)</td>
<td>9.5</td>
<td>13.0</td>
</tr>
<tr>
<td>12.5 mm DFP Sheathing</td>
<td>4:1 (^3)</td>
<td>11.6</td>
<td>17.2</td>
</tr>
<tr>
<td>9 mm OSB 2R24/W24</td>
<td>4:1 (^3)</td>
<td>9.6</td>
<td>14.3</td>
</tr>
<tr>
<td>11 mm OSB 1R24/2F16/W24</td>
<td>4:1 (^3)</td>
<td>9.9</td>
<td>14.6</td>
</tr>
</tbody>
</table>

1. For SI: 1” = 25.4 mm, 1 foot = 0.305 m, 1 lb = 4.45 N.
2. See Section B5.2.2.3.6 for requirements for sheathing applied to both sides of wall.
3. See Section B5.2.2.1 for Type I shear wall height-to-length aspect ratios \((h/w)\) greater than 2:1, but not exceeding 4:1.
### Table B5.2.2.3-3
**Unit Nominal Shear Strength [Resistance] \( (v_n) \)¹ ²**
For Shear Walls with Gypsum Board Panel Sheathing on One Side of Wall

<table>
<thead>
<tr>
<th>Sheathing</th>
<th>Maximum Aspect Ratio ( (h/w) )</th>
<th>Fastener Spacing at Panel Edges/Field ( (\text{inches}) )</th>
<th>Designation Thickness of Stud, Track and Blocking ( (\text{mils}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>8/12</td>
<td>4/12</td>
</tr>
<tr>
<td>½” gypsum board</td>
<td>2:1</td>
<td>230</td>
<td>295</td>
</tr>
<tr>
<td>Canada ( (kN/m) )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.5 mm gypsum board</td>
<td>2:1</td>
<td>2.7</td>
<td>3.1</td>
</tr>
</tbody>
</table>

1. For SI: 1” = 25.4 mm, 1 foot = 0.305 m, 1 lb = 4.45 N.
2. See Section B5.2.2.3.6 for requirements for sheathing applied to both sides of wall.

### Table B5.2.2.3-4
**Unit Nominal Shear Strength [Resistance] \( (v_n) \)¹ ²**
For Shear Walls with Fiberboard Panel Sheathing on One Side of Wall

<table>
<thead>
<tr>
<th>Sheathing</th>
<th>Maximum Aspect Ratio ( (h/w) )</th>
<th>Fastener Spacing at Panel Edges/Field ( (\text{mm}) )</th>
<th>Designation Thickness of Stud, Track and Blocking ( (\text{mils}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>200/300</td>
<td>150/300</td>
</tr>
<tr>
<td>½” fiberboard</td>
<td>1:1</td>
<td>425</td>
<td>615</td>
</tr>
<tr>
<td>Canada ( (kN/m) )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.5 mm fiberboard</td>
<td>1:1</td>
<td>100/150</td>
<td>75/150</td>
</tr>
</tbody>
</table>

1. For SI: 1” = 25.4 mm, 1 foot = 0.305 m, 1 lb = 4.45 N.
2. See Section B5.2.2.3.6 for requirements for sheathing applied to both sides of wall.
B5.2.3 Available Strength [Factored Resistance]

The available strength [factored resistance] (\(\phi_v V_n\) for LRFD and LSD or \(V_n/\Omega_v\) for ASD) shall be determined from the nominal strength [resistance] using the applicable safety factors (\(\Omega\)) or resistance factors (\(\phi\)) given in this section in accordance with the applicable design method – ASD, LRFD, or LSD as follows:

\[\Omega_v = 2.00 \text{ for ASD}\]
\[\phi_v = 0.65 \text{ for LRFD}\]
\[\phi_v = 0.70 \text{ for LSD (except gypsum and fiberboard sheathed walls)}\]
\[\phi_v = 0.60 \text{ for LSD (gypsum and fiberboard sheathed walls)}\]

B5.2.4 Collectors and Anchorage

Design of collectors and anchorage for shear walls shall conform to the requirements of this section.

B5.2.4.1 Collectors and Anchorage for In-Plane Shear

Collectors and anchorage for in-plane shear shall be designed in accordance with this section.

B5.2.4.1.1 Type I Shear Walls

The unit shear force, \(v\), transmitted into the top and out of the base of the Type I shear wall shall be determined in accordance with the following:

\[v = \frac{V}{L}\]  \(\text{(Eq. B5.2.4-1)}\)

where

\(v\) = Unit shear force, plf \([\text{kN/m}]\)
\(V\) = Shear force determined in accordance with applicable ASD, LRFD or LSD load combinations in Type I shear wall, lbs \([\text{kN}]\)
\(L\) = Length of Type I shear wall, feet \([\text{m}]\)

B5.2.4.1.2 Type II Shear Walls

The unit shear force, \(v\), transmitted into the top and out of the base of the Type II shear wall segments, and into collectors connecting Type II shear wall segments, shall be determined in accordance with the following:

\[v = \frac{V}{C_a \sum L_i}\]  \(\text{(Eq. B5.2.4-2)}\)

where

\(v\) = Unit shear force, plf \([\text{kN/m}]\)
\(V\) = Shear force determined in accordance with applicable ASD, LRFD or LSD load combinations in Type II shear wall, lbs \([\text{kN}]\)
\(C_a\) = Shear resistance adjustment factor from Table B5.2.2.2-1
\(\sum L_i\) = Sum of Lengths of Type II shear wall segments, feet \([\text{m}]\)

B5.2.4.2 Uplift Anchorage at Wall Ends

Uplift anchorage at shear wall ends shall be designed in accordance with this section.
B5.2.4.2.1 General

Where uplift anchorage resists the overturning load from the story or stories above, the anchorage shall be sized for the anchorage force resulting from the lateral forces at its level plus the story or stories above.

Hold-downs shall be designed to resist the sum of both shear wall overturning and roof uplift, as applicable.

Uplift anchorage forces are permitted to be reduced to account for dead load in accordance with the applicable building code.

B5.2.4.2.2 Type I Shear Walls

Anchorage for uplift forces due to overturning shall be provided at each end of the Type I shear wall. The uplift anchorage force contributed from each level shall be determined in accordance with the following:

\[
C = \frac{Vh}{L} \quad (Eq. \ B5.2.4-3)
\]

where

- \( C \) = Uplift anchorage force contributed from each level, lbs [kN]
- \( V \) = Shear force determined in accordance with applicable ASD, LRFD or LSD load combinations in Type I shear wall, lbs [kN]
- \( h \) = Shear wall height, feet [m]
- \( L \) = Length of Type I shear wall including anchor offsets, feet [m]

B5.2.4.2.3 Type II Shear Walls

Anchorage for uplift forces due to overturning shall be provided at each end of the Type II shear wall. For each level, the uplift anchorage force contributed shall be determined in accordance with the following:

\[
C = \frac{Vh}{C_a \sum L_i} \quad (Eq. \ B5.2.4-4)
\]

where

- \( C \) = Uplift anchorage force contributed from each level, lbs [kN]
- \( V \) = Shear force determined in accordance with applicable ASD, LRFD or LSD load combinations in Type II shear wall, lbs [kN]
- \( h \) = Shear wall height, feet [m]
- \( C_a \) = Shear resistance adjustment factor from Table B5.2.2.2-1
- \( \sum L_i \) = Sum of lengths of Type II shear wall segments, feet [m]

B5.2.4.3 Uplift Anchorage Between Type II Shear Wall Ends

In addition to the requirements of Section B5.2.4.2, Type II shear wall bottom plates at full-height sheathing locations shall be anchored for a uniform uplift force equal to the unit shear force, \( v \), determined in accordance with Section B5.2.4.1 plus any applicable roof uplift forces.

B5.2.5 Design Deflection

The deflection of a blocked Type I shear wall with steel sheet sheathing or wood structural panel sheathing shown in Tables B5.2.2.3-1 and B5.2.2.3-2 is permitted to be calculated in accordance with the following:
\[
\delta = \frac{2vh^3}{3E_sA_c b} + \omega_1 \omega_2 \frac{vh}{\rho G t_{\text{sheathing}}} + \omega_1^{5/4} \omega_2 \omega_3 \omega_4 \left(\frac{v}{\beta}\right)^2 + \frac{h}{b} \delta_v
\]  
(Eq. B5.2.5-1)

where

- \(A_c\) = Gross cross-sectional area of chord member, in square inches (mm²)
- \(b\) = Length of the shear wall, in inches (mm)
- \(E_s\) = Modulus of elasticity of steel
  = 29,500,000 psi (203,000 MPa)
- \(G\) = Shear modulus of sheathing material, in pounds per square inch (MPa)
- \(h\) = Wall height, in inches (mm)
- \(s\) = Maximum fastener spacing at panel edges, in inches (mm)
- \(t_{\text{sheathing}}\) = Nominal panel thickness, in inches (mm)
- \(t_{\text{stud}}\) = Framing designation thickness, in inches (mm)
- \(v\) = Shear demand, in pounds per linear inch (N/mm)
  = \(V/b\)  
  
\(V\) = Total lateral load applied to the shear wall, in pounds (N)

\(\beta\) = 67.5 for plywood other than Canadian Soft Plywood (CSP),
  = 55 for OSB and CSP for U.S. Customary units (lb/in\(^1.5\))
  = 2.35 for plywood other than CSP,
  = 1.91 for OSB and CSP for SI units (N/mm\(^1.5\))
  = 29.12(\(t_{\text{sheathing}}/0.018\)) for sheet steel (for \(t_{\text{sheathing}}\) in inches)  
  
\(\delta\) = Calculated deflection, in inches (mm)

\(\delta_v\) = Vertical deformation of anchorage/attachment details, in inches (mm)

\(\rho\) = 1.85 for plywood other than CSP, 1.05 for OSB and CSP
  = 0.075 \times \left(\frac{t_{\text{sheathing}}}{0.018}\right) for sheet steel (for \(t_{\text{sheathing}}\) in inches)
  
\(\omega_1\) = \(s/6\) (for \(s\) in inches) and \(s/152.4\) (for \(s\) in mm)

\(\omega_2\) = \(0.033/t_{\text{stud}}\) (for \(t_{\text{stud}}\) in inches) and
  = \(0.838/t_{\text{stud}}\) (for \(t_{\text{stud}}\) in mm)

\(\omega_3\) = \(\sqrt{\left(\frac{h}{b}\right)}\)  
  
\(\omega_4\) = 1 for wood structural panels

\(\omega_4\) = \(\frac{33}{F_y}\) (for \(F_y\) in ksi)  
  
\(\omega_4\) = \(\frac{227.5}{F_y}\) (for \(F_y\) in MPa) for sheet steel

The deflection of a Type I shear wall with gypsum panel sheathing or fiberboard sheathing or Type II shear wall shall be determined by principles of mechanics considering the deformation of the sheathing and its attachment, chord studs and hold-downs.
B5.3 Strap Braced Wall Design

*Strap braced walls* shall be designed in accordance with the requirements of this section and shall be installed in accordance with the requirements of Section C3.6.2.

**User Note:**
See Section A1.3 for applicability of this section to cold-formed steel structural members and connections in seismic force-resisting systems.

B5.3.1 General

The height-to-length aspect ratio of a *strap braced wall* shall not exceed 2:1 unless a *rational engineering analysis* is performed which includes joint flexibility and end moments in the design of the *chord studs*.

B5.3.2 Nominal Strength [Resistance]

The *nominal strength [resistance]* for the *strap, connections, and chord studs* shall be determined in accordance with AISI S100.

B5.3.3 Available Strength [Factored Resistance]

The *available strength [factored resistance]* for the *strap, connections, and chord studs* shall be determined in accordance with AISI S100.

B5.3.4 Collectors and Anchorage

Design of *collectors* and anchorage for *strap braced walls* shall conform to the requirements of this section.

B5.3.4.1 Collectors and Anchorage for In-Plane Shear

Collectors and anchorage shall be designed to transmit the shear force into the top and out of the base of the *strap braced wall*.

B5.3.4.2 Uplift Anchorage at Wall Ends

Where uplift anchorage resists the overturning load from the story or stories above, the anchorage shall be sized for the anchorage force at its level plus the anchorage force of the story or stories above.

*Hold-downs* shall be designed to resist the sum of both *strap braced wall* overturning and roof uplift, as applicable.

Uplift anchorage forces are permitted to be reduced to account for dead load in accordance with the *applicable building code*.

Anchorage for uplift forces due to overturning shall be provided at each end of the *strap braced wall*. Uplift anchorage and boundary chord forces shall be determined in accordance with the following:

\[
C = \frac{Vh}{L} \quad (Eq. \ B5.3.4.2-1)
\]

where

- \( C \) = Boundary chord force (tension/compression), lbs [kN]
- \( V \) = Shear force determined in accordance with applicable *ASD, LRFD* or *LSD load combinations* in *strap braced wall*, lbs [kN]
\[ h = \text{Strap braced wall height, feet [m]} \]
\[ L = \text{Length of strap braced wall including anchor offsets, feet [m]} \]

**B5.3.5 Design Deflection**

The deflection of a strap braced wall shall be determined by principles of mechanics considering the deformation of the strap, chord studs and hold-downs.

**B5.4 Diaphragm Design**

Diaphragms shall be designed based on principles of mechanics in accordance with Section B1.2.6 or tests in accordance with Section B5.4.5. Alternatively, in the United States and Mexico, diaphragms sheathed with wood structural panels are permitted to be designed as either blocked diaphragms or unblocked diaphragms in accordance with the requirements of Sections B5.4.1 through B5.4.4 and shall be installed in accordance with the requirements of Section C3.6.3.

**B5.4.1 General**

Diaphragms shall conform to the following requirements:

(a) The aspect ratio (length/width) of the diaphragm does not exceed 4:1 for blocked diaphragms and 3:1 for unblocked diaphragms.

(b) Joists and track are ASTM A1003 Structural Grade 33 (Grade 230) Type H steel for members with a designation thickness of 33 and 43 mils, and ASTM A1003 Structural Grade 50 (Grade 340) Type H steel for members with a designation thickness equal to or greater than 54 mils.

(c) The minimum designation thickness of structural members is 33 mils.

(d) Joists are C-shape members with a minimum flange width of 1-5/8 in. (41.3 mm), minimum web depth of 3-1/2 in. (89 mm) and minimum edge stiffener of 3/8 in. (9.5 mm).

(e) Track has a minimum flange width of 1-1/4 in. (31.8 mm) and a minimum web depth of 3-1/2 in. (89 mm).

(f) Screws for structural members are a minimum No. 8 and are in accordance with ASTM C1513.

(g) Wood structural panel sheathing is manufactured using exterior glue and complies with DOC PS 1 or PS 2.

(h) Screws used to attach wood structural panels are minimum No. 8 where structural members have a designation thickness of 54 mils or less and No. 10 where structural members have a designation thickness greater than 54 mils and are in accordance with ASTM C1513.

(i) Screws in the field of the panel are attached to intermediate supports at a maximum 12-inch (305 mm) spacing along the structural members.

(j) Panels less than 12 inches (305 mm) wide are not used.

(k) Maximum joist spacing is 24 inches (610 mm) on center.

(l) Where diaphragms are designed as blocked, all panel edges are attached to structural members or panel blocking.

(m) Where used as panel blocking, flat strap is a minimum thickness of 33 mils with a minimum width of 1-1/2 inches (38.1 mm).
### B5.4.2 Nominal Strength

The *nominal strength* per unit length for blocked and unblocked assemblies shall be as specified in Table B5.4.2-1.

Tabulated values in Table B5.4.2-1 are applicable for short-term load duration only (wind or seismic loads). For *loads* of normal or permanent load duration as defined by the AWC NDS, the values shall be multiplied by 0.75 (normal) or 0.67 (permanent).

#### Table B5.4.2-1
Nominal Shear Strength ($R_n$) per Unit Length for Diaphragms With Wood Structural Panel Sheathing

<table>
<thead>
<tr>
<th>Sheathing</th>
<th>Thickness (in.)</th>
<th>Blocked</th>
<th>Unblocked</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Screw spacing at diaphragm boundary edges and at all continuous panel edges (in.)</td>
<td>Screws spaced maximum of 6 in. on all supported edges</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Screw spacing at all other panel edges (in.)</td>
<td>Load perpendicular to unblocked edges and continuous panel joints</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Structural I</td>
<td>3/8</td>
<td>768</td>
<td>1022</td>
</tr>
<tr>
<td></td>
<td>7/16</td>
<td>768</td>
<td>1127</td>
</tr>
<tr>
<td></td>
<td>15/32</td>
<td>925</td>
<td>1232</td>
</tr>
<tr>
<td>C-D, C-C and other graded wood structural panels</td>
<td>3/8</td>
<td>690</td>
<td>920</td>
</tr>
<tr>
<td></td>
<td>7/16</td>
<td>760</td>
<td>1015</td>
</tr>
<tr>
<td></td>
<td>15/32</td>
<td>832</td>
<td>1110</td>
</tr>
</tbody>
</table>

1. For SI: 1 in. = 25.4 mm, 1 foot = 0.305 m, 1 lb = 4.45 N.

### B5.4.3 Available Strength

The *available strength* ($\phi_v V_n$ for LRFD or $V_n/\Omega_v$ for ASD) shall be determined from the *nominal strength* using the applicable safety factors ($\Omega$) or resistance factors ($\phi$) given in this section in accordance with the applicable design method — ASD or LRFD, as follows:

$\Omega_v = 2.00$ (ASD)
$\phi_v = 0.65$ (LRFD)

### B5.4.4 Design Deflection

The deflection of a blocked *diaphragm* with *wood structural panel* sheathing shown in Table B5.4.2-1 is permitted to be calculated in accordance with Section B5.4.4.1. The deflection of an unblocked *diaphragm* with *wood structural panel* sheathing shown in Table B5.4.2-1 is permitted to be calculated in accordance with Section B5.4.4.2.
**B5.4.4.1 Blocked Diaphragms**

The deflection of a blocked diaphragm, $\delta_b$, is permitted to be determined in accordance with the following:

$$\delta_b = \frac{0.052vL^3}{E_sA_c b} + \omega_1 \omega_2 \frac{vL}{\rho Gt_{sheathing}} + \omega_1^{5/4} \omega_2 (\alpha \left( \frac{v}{2\beta} \right)^2 + \sum_{i=1}^{n} \Delta_{ci} X_i) \quad (Eq. \ B5.4.4-1)$$

where

- $A_c$ = Gross cross-sectional area of chord member, in square inches (mm$^2$)
- $b$ = Diaphragm depth parallel to direction of load, in inches (mm)
- $E_s$ = Modulus of elasticity of steel
  = 29,500,000 psi (203,000 MPa)
- $G$ = Shear modulus of sheathing material, in pounds per square inch (MPa)
- $L$ = Diaphragm length perpendicular to direction of load, in inches (mm)
- $n$ = Number of chord splices in diaphragm (considering both diaphragm chords)
- $s$ = Maximum fastener spacing at panel edges, in inches (mm)
- $t_{sheathing}$ = Nominal panel thickness, in inches (mm)
- $t_{stud}$ = Nominal framing thickness, in inches (mm)
- $v$ = Shear demand, in pounds per linear inch (N/mm)
  = $V/(2b)$ \hspace{1cm} (Eq. B5.4.4-2)
- $V$ = Total lateral load applied to the diaphragm, in pounds (N)
- $X_i$ = Distance between the "ith" chord-splice and the nearest support, in inches (mm)
- $\alpha$ = Ratio of the average load per fastener based on a non-uniform fastener pattern to the average load per fastener based on a uniform fastener pattern (= 1 for a uniformly fastened diaphragm)
- $\beta$ = 67.5 for plywood other than Canadian Soft Plywood (CSP)
  = 55 for OSB and CSP for U.S. Customary units (lb/in$^1.5$)
  = 2.35 for plywood other than CSP
  = 1.91 for OSB for SI units (N/mm$^1.5$)
- $\delta_b$ = Calculated deflection, in inches (mm)
- $\Delta_{ci}$ = Deformation value associated with "ith" chord splice, in inches (mm)
- $\rho$ = 1.85 for plywood other than CSP
  = 1.05 for OSB and CSP
- $\omega_1$ = $s/6$ (for $s$ in inches) \hspace{1cm} (Eq. B5.4.4-3a)
  = $s/152.4$ (for $s$ in mm) \hspace{1cm} (Eq. B5.4.4-3b)
- $\omega_2$ = $0.033/t_{stud}$ (for $t_{stud}$ in inches) \hspace{1cm} (Eq. B5.4.4-4a)
  = $0.838/t_{stud}$ (for $t_{stud}$ in mm) \hspace{1cm} (Eq. B5.4.4-4b)

**B5.4.4.2 Unblocked Diaphragms**

The deflection of an unblocked diaphragm, $\delta_{ub}$, is permitted to be determined in accordance with the following:

$$\delta_{ub} = 2.50 \delta_b \quad (Eq. \ B5.4.4-5)$$
where
\[ \delta_b = \text{Deflection of blocked diaphragm determined in accordance with Eq. B5.4.4-1} \]

**B5.4.5 Beam Diaphragm Tests for Non-Steel Sheathed Assemblies**

For buildings with the maximum aspect ratio of 4:1 and having cold-formed steel roof or floor assemblies having non-steel sheathing, the in-plane diaphragm nominal shear strength [resistance], \( S_n \), shall be in accordance with Table B5.4.2-1 where applicable or shall be established by test in accordance with ASTM E455 and AISI S100 Section F1.1(a).

When the failure mode of the assembly is identified to be in the cold-formed steel members or sheathing-to-steel fasteners, safety factors shall not be less than and resistance factors shall not be greater than those prescribed by Section B5.2.3 when determined in accordance with the procedures of AISI S100 Section F1.1 with the following definitions of the variables:

- \( \beta_o = \text{Target reliability index} \)
  - = 2.5 for USA and Mexico and
  - = 3.0 for Canada
- \( F_m = \text{Mean value of the fabrication factor} \)
  - = 1.0
- \( M_m = \text{Mean value of the material factor} \)
  - = 1.1
- \( V_M = \text{Coefficient of variation of material factor} \)
  - = 0.10
- \( V_F = \text{Coefficient of variation of fabrication factor} \)
  - = 0.10
- \( V_Q = \text{Coefficient of variation of the load effect} \)
  - = 0.21
- \( V_P = \text{Actual calculated coefficient of variation of the test results, without limit} \)
- \( n = \text{Number of connections in the assembly with the same tributary area} \)

When the failure mode of the assembly is identified to be in the sheathing material, a safety factor of 2.8 and resistance factor of 0.6 shall be used.
C. INSTALLATION

C1 General

Structural members and connections shall be installed in accordance with the requirements of this section, as applicable.

C2 Material Condition

The following requirements shall apply to structural members, connectors, hold-downs and mechanical fasteners:
(a) Structural members, connectors, hold-downs and mechanical fasteners shall be as specified by the approved construction documents.
(b) Damaged structural members, connectors, hold-downs and mechanical fasteners shall be replaced or repaired in accordance with an approved design or as specified by a registered design professional.

C2.1 Web Holes

Holes in webs of framing members shall be in conformance with AISI S100 [CSA S136], the approved construction documents, or shall be reinforced or patched in accordance with an approved design as specified by a registered design professional.

C2.2 Cutting and Patching

C2.2.1 All cutting of framing members shall be done by sawing, abrasive cutting, shearing, plasma cutting or other approved methods acceptable to the registered design professional.
C2.2.2 Cutting or notching of structural members, including flanges and lips of joists, studs, headers, rafters, and ceiling joists, shall be permitted with an approved design or as specified by a registered design professional.
C2.2.3 Patching of cuts and notches shall be permitted with an approved design or as specified by a registered design professional.

C2.3 Splicing

Splicing of joists, studs and other structural members shall be permitted with an approved design or as specified by a registered design professional.

C3 Structural Framing

Structural members shall be installed in accordance with the requirements of this section, as applicable.

C3.1 Foundation

The foundation shall be level and free from defects beneath structural walls. If the foundation is not level, provisions shall be made to provide a uniform bearing surface with a maximum 1/4 inch (6.4 mm) gap between the bottom track or rim track and the foundation. This shall be accomplished through the use of load bearing shims or grout provided between the underside of the wall bottom track or rim track and the top of the foundation wall or slab at stud or joist locations.
C3.2 Ground Contact

Framing shall not be in direct contact with the ground unless permitted by an approved design. Framing not in direct contact with the ground shall be installed at a height above the ground in accordance with the applicable building code.

C3.3 Floors

C3.3.1 Plumbness and Levelness

Floor joists and floor trusses shall be installed plumb and level, except where designed as sloping members.

C3.3.2 Alignment

Floor joists and floor trusses shall comply with the in-line framing requirements of Section B1.2.3 and floor sheathing span capacity requirements of Section B1.2.4, as applicable.

C3.3.3 Bearing Width

Floor joists and floor trusses shall be installed with full bearing over the width of the bearing wall beneath, a minimum 1-1/2 inch (38 mm) bearing end, or in accordance with an approved design or as specified by a registered design professional.

C3.3.4 Web Separation

Floor joist webs shall not be in direct contact with rim track webs.

C3.4 Walls

C3.4.1 Straightness, Plumbness and Levelness

Wall studs shall be installed plumb and walls shall be level in accordance with ASTM C1007, except where designed as sloping members.

C3.4.2 Alignment

Structural wall studs shall comply with the in-line framing requirements of Section B1.2.3 and wall sheathing span capacity requirements of Section B1.2.4, as applicable.

C3.4.3 Stud-to-Track Connection

The connection between the stud flange and the track flange shall meet the requirements of Section B3.2.5 and shall permit both ends of the wall stud to be connected to the track to restrain rotation about the longitudinal wall stud axis and horizontal displacement perpendicular to the wall stud axis. Further, the maximum gap between the end of the stud and the track web shall also comply with the following, as applicable:

(a) Ends of axial load bearing wall studs 54 mils and less shall have square end cuts and shall be seated tight against the track with a gap that does not exceed 1/8 in. (3.2 mm) between the end of the wall framing member and the web of the track. For thicknesses of the stud or track greater than 54 mil (0.054 inches (1.37mm)), the maximum end gap shall be specified by the registered design professional.

(b) Ends of curtain wall studs shall have square end cuts and shall be seated in the track with
a gap that does not exceed 1/4 in. (6.4 mm) between the end of the wall stud and the web of the track, unless otherwise accepted by a registered design professional.

C3.4.4 Back-to-Back and Box Headers

Back-to-back and box headers designed in accordance with this Standard shall be installed in accordance with Figures C3.4.4-1 and C3.4.4-2, respectively. For box headers, it is permitted to connect track flanges to the webs of C-shape sections using 1-inch (25.4 mm) fillet welds spaced at 24 inches (610 mm) on center in lieu of No. 8 screws.

C3.4.5 Double and Single L-Headers

Double and single L-headers designed in accordance with this Standard shall be installed in accordance with Figures C3.4.5-1 and C3.4.5-2, respectively.

C3.4.6 Inverted L-Header Assemblies

Inverted double or single L-headers designed in accordance with this Standard shall be installed in accordance with the following:

1. The horizontal leg of the inverted L-header shall be coped to permit the vertical leg to lap over at least one bearing stud at each end. The horizontal leg after coping shall be within 1/2 inch (12.7 mm) of the bearing stud at each end.

2. The horizontal leg of the inverted L-header shall be attached to the head track at each end and at 12 inches (304.8 mm) on center with minimum #8 screws.

3. The vertical leg of the inverted L-header shall be attached to at least one bearing stud at each end and each cripple stud with a minimum No. 8 screw top and bottom. The top screw in the vertical leg of the inverted L-header shall be located not more than 1 inch (25.4 mm) from the top edge of the vertical leg.
C3.5 Roofs and Ceilings

C3.5.1 Plumbness and Levelness

Roof and ceiling framing members shall be installed plumb and level, except where designed as sloping members.

C3.5.2 Alignment

Roof and ceiling framing members shall comply with the in-line framing requirements of Section B1.2.3 and roof sheathing span capacity requirements of Section B1.2.4, as applicable.

C3.5.3 End Bearing

Ceiling joists and roof trusses shall be installed with full bearing over the width of the bearing wall beneath, or a minimum 1-1/2 inch (38 mm) bearing end condition, or in accordance with an approved design or as specified by a registered design professional.

C3.6 Lateral Force-Resisting Systems

C3.6.1 Shear Walls

The installation of shear walls designed in accordance with this Standard shall conform to the following requirements:

(a) Fasteners along the edges in shear panels are placed from panel edges not less than the following, as applicable:
   (1) In the United States and Mexico, 3/8 in. (9.5 mm).
   (2) In Canada, 12.5 mm (1/2 in.).

(b) Where used as panel blocking with steel sheet sheathing, flat strap is installed on top of or below the sheathing. Where used as panel blocking with other than steel sheet sheathing, flat strap is installed below the sheathing.

(c) Where panel blocking is used with other than steel sheet sheathing, the screws are installed through the sheathing to the panel blocking.

C3.6.2 Strap Braced Walls

No additional provisions.

C3.6.3 Diaphragms

The installation of diaphragms sheathed with wood structural panels and designed in accordance with this Standard shall conform to the following requirements:

(a) Fasteners along the edges in shear panels are placed from panel edges not less than 3/8 in. (9.5 mm).

(b) Where used as panel blocking, flat strap is installed below the sheathing.

(c) Where panel blocking is used, the screws are installed through the sheathing to the panel blocking.

C4 Connections

Connections shall be installed in accordance with the requirements of this section, as applicable.
C4.1 Screw Connections

C4.1.1 Steel-to-Steel Screws

Use of a larger-than-specified screw size is permitted if the installation is in accordance with the minimum design spacing and edge distance.

C4.1.2 Installation

C4.1.2.1 Screw fasteners shall extend through the steel connection with a minimum of three (3) exposed threads.

C4.1.2.2 Screw fasteners shall penetrate individual components of connections without causing permanent separation between components.

C4.1.3 Stripped Screws

C4.1.3.1 Stripped screw fasteners in direct tension shall not be considered effective.

C4.1.3.2 Stripped screw fasteners in shear shall only be considered effective when the number of stripped screw fasteners considered effective does not exceed 25% of the total number of screw fasteners considered effective in the connection.

C4.2 Welded Connections

Welded areas shall be protected with an approved treatment to retain the corrosion resistance of the welded area.

C5 Miscellaneous

Utilities and insulation shall be installed in accordance with the requirements of this section, as applicable.

C5.1 Utilities

C5.1.1 Holes

C5.1.1.1 Holes shall comply with the requirements specified in Section C2.1.

C5.1.1.2 Penetrations of floor, wall and ceiling/roof assemblies which are required to have a fire resistance rating shall be protected in accordance with the approved construction documents.

C5.1.2 Plumbing

All piping shall be provided with an isolative non-corrosive system to prevent galvanic action or abrasion between framing members and piping.

C5.1.3 Electrical

Wiring not enclosed in metal conduit shall be separated from the framing members by nonconductive, noncorrosive grommets or by other approved means.
C5.2 Insulation

C5.2.1 Mineral Fiber Insulation

Mineral fiber insulation (e.g., rock wool, glass fiber, etc.) for installation within cavities of framing members shall be full-width type insulation and shall be installed in accordance with the applicable building code and insulation manufacturer’s requirements. Compression of the insulation is permitted to occur at the open side of the C-shaped framing member.

C5.2.2 Other Insulation

Other types of insulation (e.g., foams, loose fill, etc.) for installation within cavities of framing members shall be installed in accordance with the applicable building code and insulation manufacturer’s requirements. The width of insulation shall be dimensionally compatible with the cold-formed steel framing.
D. QUALITY CONTROL AND QUALITY ASSURANCE

D1 General

D1.1 Scope and Limits of Applicability

Chapter D provides minimum requirements for quality control and quality assurance for material control, component manufacturing, and installation for cold-formed steel light-frame construction. Minimum observation and inspection tasks deemed necessary to ensure quality cold-formed steel light-frame construction are specified.

D1.2 Responsibilities

Quality control as specified in this chapter shall be provided by the component manufacturer and installer, as applicable. Quality assurance as specified in this chapter shall be provided by others where required by the authority having jurisdiction, the applicable building code, the owner, or the registered design professional.

D2 Quality Control Programs

D2.1 The component manufacturer shall establish and maintain quality control procedures and perform inspections to ensure that the work is in accordance with this Standard and the shop drawings.

D2.2 The installer shall establish and maintain quality control procedures and perform inspections to ensure that the work is in accordance with this Standard and the construction documents.

D2.3 Product identification shall comply with the requirements of Section A5.5, and shall be monitored by the component manufacturer’s and installer’s quality control inspectors, as applicable.

D2.4 Where part of a component assembly, the component manufacturer’s quality control inspector shall perform inspections of the following items, as applicable:

(a) Cold-formed steel structural members and connectors in accordance with Section D6.5.
(b) Shop welding in accordance with Section D6.6.
(c) Mechanical fastening in accordance with Section D6.7.

D2.5 The installer’s quality control inspector shall perform inspections of the following, as applicable:

(a) Cold-formed steel structural members and connectors that are not part of a component assembly in accordance with Section D6.5.
(b) Field welding in accordance with Section D6.6.
(c) Mechanical fastening that is not part of a component assembly in accordance with Section D6.7.
(d) Installation of cold-formed steel light-frame construction in accordance with Section D6.8.
(e) Installation of cold-formed steel lateral force-resisting systems in accordance with Section D6.9.
(f) Damage to cold-formed steel structural members and connectors, including component assemblies damaged during or after delivery to the project.
D3 Quality Control Documents

D3.1 Documents to be Submitted

The component manufacturer and installer shall submit the following documents to the registered design professional and contractor for review prior to the installation of the cold-formed steel light-frame construction:

(a) Shop drawings, unless shop drawings have been furnished by others.
(b) Installation drawings, unless installation drawings have been furnished by others.
(c) Product data sheets, catalogue data or independent evaluation reports on cold-formed steel structural members, including material, corrosion protection, base steel thickness, and dimensions. Alternatively, material, corrosion protection, base steel thickness, and dimensions shall be shown on the installation drawings.
(d) Product data sheets, catalogue data or independent evaluation reports on connectors and mechanical fasteners.

D3.1.1 Additional Requirements for Lateral Force-Resisting Systems

D3.1.1.1 Component Assemblies

For component assemblies, the component manufacturer shall submit the following additional documents, as applicable, to the registered design professional and contractor for approval prior to the installation of the cold-formed steel lateral force resisting system elements:

(a) Welding procedure specifications.
(b) Mechanical fastener installation procedures.
(c) Product data sheets, catalogue data or independent evaluation reports on hold-downs.

D3.1.1.2 Other Than Component Assemblies

For other than component assemblies, the installer shall submit the following additional documents, as applicable, to the registered design professional and contractor for approval prior to the installation of the cold-formed steel lateral force-resisting system elements:

(a) Welding procedure specifications.
(b) Mechanical fastener installation procedures.
(c) Product data sheets, catalogue data or independent evaluation reports on hold-downs.

D3.1.1.3 Exceptions to Sections D3.1.1.1 and D3.1.1.2

The additional requirements in Section D3.1.1.1 and Section D3.1.1.2 are not required for cold-formed steel lateral force-resisting systems where either of the following apply:

(a) The sheathing of the shear wall is gypsum board or fiberboard.
(b) The sheathing is wood structural sheathing or steel sheet sheathing on only one side of the shear wall or diaphragm assembly and the fastener spacing of the sheathing is more than 4 inches (102 mm) on center (o.c.).

D3.2 Available Documents

Unless required for submittal by the registered design professional, the following documents, as applicable and upon request, shall be made available by the component manufacturer or installer,
as applicable, in electronic or printed form to the registered design professional and contractor for review prior to installation of the cold-formed steel light-frame construction:

(a) Manufacturer’s installation instructions for connectors, hold-downs and mechanical fasteners.
(b) Manufacturer’s product data sheets or catalog data for welding consumables, filler metals and fluxes that include the product, limitations of use, recommended or typical welding parameters, and storage and exposure requirements.
(c) Welding procedure specifications.
(d) Procedure qualification records for welding procedure specifications that are not prequalified in accordance with AWS D1.3, as applicable.
(e) Welding personnel performance qualification records and continuity records.
(f) Component manufacturer’s and installer’s written quality control program(s) that include material control procedures, inspection procedures, and nonconformance procedures.
(g) Component manufacturer’s and installer’s quality control inspector qualifications.

D4 Quality Assurance Agency Documents

The agency responsible for quality assurance shall submit the following documents to the authority having jurisdiction, registered design professional and owner, as applicable:

(a) Quality assurance agency’s written practices for the monitoring and control of the agency’s operations. The written practice shall include:
   (1) The agency’s procedures for the selection and administration of inspection personnel, describing the training, experience and examination requirements for qualification and certification of inspection personnel.
   (2) The agency’s inspection procedures, including general inspection, material controls, and visual welding inspection.
(b) Qualifications of management designated for the project.
(c) Qualification records for inspectors designated for the project.

D5 Inspection Personnel

D5.1 Quality Control Inspector

D5.1.1 A quality control inspector shall be designated as the person with overall responsibility for quality control. It is permitted to delegate specific quality control tasks to qualified personnel.

D5.1.2 Quality control welding inspection personnel shall be qualified in accordance with the component manufacturer’s or installer’s quality control program, as applicable, and in accordance with one of the following:
   (a) Associate Welding Inspector (AWI) or higher as defined in AWS B5.1.
   (b) Qualified by training or experience, or both, in cold-formed steel light-frame construction component manufacturing, installation, inspection, or testing and competent to perform inspection of the work.

D5.1.3 Quality control mechanical fastener inspection personnel shall be qualified in accordance with the installer’s quality control program on the basis of training and experience in installation of similar fasteners and shall be competent to perform inspection of the work.
**D5.2  Quality Assurance Inspector**

**D5.2.1** The approved quality assurance inspector shall be designated as the person with overall responsibility for quality assurance. The approved quality assurance inspector is permitted to delegate specific quality assurance tasks to qualified personnel.

**D5.2.2** Quality assurance welding inspection personnel shall be qualified in accordance with the quality assurance agency’s written practice and with either of the following:

(a) Welding Inspector (WI) or higher as defined in AWS B5.1, except Associate Welding Inspectors (AWI) shall be permitted to be used under the direct supervision of WIs or higher who are on the premises and available when weld inspection is being conducted; or

(b) Qualified by training or experience, or both, in cold-formed steel light-frame construction installation, inspection or testing and competent to perform inspection of the work.

**D5.2.3** Quality assurance mechanical fastener inspection personnel shall be qualified in accordance with the quality assurance agency’s written practice on the basis of training and experience in inspection of similar fasteners.

**D6  Inspection Tasks**

**D6.1  General**

Inspection tasks and documentation for quality control and quality assurance shall be in accordance with the tables in Sections D6.5, D6.6, D6.7, D6.8, and D6.9. These tables specify distinct inspection tasks as follows:

(a) **Observe.** Observe shall mean to perform inspection of these items on an intermittent basis. Operations that do not interfere with the ability to perform inspection of these items need not be delayed pending these inspections. Frequency of observations shall be adequate to confirm that the work has been performed in accordance with the applicable documents.

(b) **Perform.** Perform shall mean to execute these tasks prior to final acceptance for each item or element.

(c) **Document.** Within the listed tasks, document shall mean the inspector shall prepare reports or other written documentation indicating that the work has or has not been performed in accordance with the construction documents.

**D6.2  Quality Control Inspection Tasks**

**D6.2.1** Quality control inspection tasks shall be performed by the component manufacturer’s or installer’s quality control inspector, as applicable, in accordance with Sections D6.6 through D6.10. Tasks in the tables in Sections D6.5 through D6.9 listed for QC shall be those inspections performed by the quality control inspector to ensure that the work is performed in accordance with the construction documents.

**D6.2.2** Quality control inspection shall utilize the following, as applicable: construction documents, installation drawings, shop drawings, plans, specifications or referenced standards.

**D6.3  Quality Assurance Inspection Tasks**

**D6.3.1** Quality assurance inspection of the component assemblies shall be made at the component manufacturer’s plant. The quality assurance inspector shall schedule this work to minimize interruptions to the work of the component manufacturer.
D6.3.2 Quality assurance inspection of the cold-formed steel light-frame construction shall be made at the project site. The contractor shall schedule this work with the quality assurance inspector and the installer to minimize interruptions to the work of the installer.

D6.3.3 The quality assurance inspector shall review the materials test reports and certifications listed in Section D3.2 for compliance with the construction documents.

D6.3.4 Quality assurance tasks shall be performed by the quality assurance inspector, in accordance with Sections D6.5 through D6.9. Tasks in the tables in Sections D6.5 through D6.9 listed for QA shall be those inspections performed by the quality assurance inspector to ensure that the work is performed in accordance with the construction documents.

D6.3.5 Concurrent with the submittal of reports to the authority having jurisdiction, registered design professional and owner, as applicable, the quality assurance inspector shall submit to the contractor and the installer lists of nonconforming items.

D6.4 Coordinated Inspection

D6.4.1 Where a task is noted to be performed by both quality assurance and quality control, it is permitted to coordinate inspection function between the quality control inspector and quality assurance inspector so that the inspection functions are performed by only one party when approved in advance by the owner, registered design professional, and authority having jurisdiction.

D6.4.2 Where quality assurance tasks are performed only by the quality control inspector, each inspection shall be documented in a report and the quality assurance inspector shall periodically review the work of the quality control inspector at an interval acceptable to the owner, registered design professional, and authority having jurisdiction.

D6.5 Material Verification

D6.5.1 The component manufacturer’s quality control inspector shall perform inspections of the cold-formed steel structural members and connectors used in component assemblies to verify compliance with the details shown on the shop drawings.

D6.5.2 The installer’s quality control inspector shall perform inspections of the cold-formed steel structural members and connectors that are not part of a component assembly to verify compliance with the details shown on the installation drawings.

D6.5.3 The quality assurance inspector shall perform verifications and inspections, as applicable, to verify compliance with the construction documents and this Standard.

D6.5.4 Inspection tasks shall be in accordance with Tables D6.5-1 and D6.5-2.
Table D6.5-1
Material Verification Tasks
Prior to Assembly or Installation

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
</table>
| A Verify compliance of cold-formed steel structural members:  
- Product identification (Section A5.5) | Perform | Perform |
| B Verify compliance of connectors | Perform | Perform |
| C Document acceptance or rejection of cold-formed steel structural members and connectors | Not Required<sup>1</sup> | Perform |

<sup>1</sup> Documentation tasks for quality control should be as defined by the applicable quality control program of the component manufacturer or installer.

Table D6.5-2
Material Verification Tasks
After Assembly or Installation

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
</table>
| A Verify compliance of cold-formed steel structural members:  
- Product identification (Section A5.5) | Perform | Perform |
| B Verify compliance of connectors | Perform | Perform |
| C Document acceptance or rejection of cold-formed steel structural members and connectors | Not Required<sup>1</sup> | Perform |

<sup>1</sup> Documentation tasks for quality control should be as defined by the applicable quality control program of the component manufacturer or installer.

D6.6 Inspection of Welding

D6.6.1 Observation of welding operations and visual inspection of in-process and completed welds shall be the primary method to confirm that the materials, procedures and workmanship are in conformance with the construction documents and AWS D1.3.

D6.6.2 Welding inspection tasks shall be in accordance with Tables D6.6-1, D6.6-2 and D6.6-3.

Table D6.6-1
Inspection or Execution Tasks  
Prior to Welding

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Welding procedure specifications available</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>B Manufacturer certifications for welding consumables available</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>C Material identification (type/grade)</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>D Check welding equipment</td>
<td>Observe</td>
<td>Observe</td>
</tr>
</tbody>
</table>
Table D6.6-2
Inspection or Execution Tasks During Welding

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Use of qualified welders</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>B Control and handling of welding consumables</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>C Environmental conditions (wind speed, moisture, temperature)</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>D Welding procedure specifications followed</td>
<td>Observe</td>
<td>Observe</td>
</tr>
</tbody>
</table>

Table D6.6-3
Inspection or Execution Tasks After Welding

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Verify compliance of welds</td>
<td>Perform</td>
<td>Perform</td>
</tr>
<tr>
<td>B Welds meet visual acceptance criteria</td>
<td>Perform</td>
<td>Perform</td>
</tr>
<tr>
<td>C Verify repair activities</td>
<td>Perform</td>
<td>Perform</td>
</tr>
<tr>
<td>D Document acceptance or rejection of welded connections</td>
<td>Not Required ¹</td>
<td>Perform</td>
</tr>
</tbody>
</table>

¹ Documentation tasks for quality control should be as defined by the applicable quality control program of the component manufacturer or installer.

D6.7 Inspection of Mechanical Fastening

D6.7.1 Observation of mechanical fastening operations and visual inspection of in-process and completed connections shall be the primary method to confirm that the materials, procedures and workmanship are in conformance with the construction documents and manufacturer’s installation instructions.

D6.7.2 Mechanical fastening inspection tasks shall be in accordance with Tables D6.7-1, D6.7-2 and D6.7-3.

Table D6.7-1
Inspection or Execution Tasks Prior to Mechanical Fastening

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Mechanical fastener manufacturer installation instructions available for mechanical fasteners</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>B Proper tools available for mechanical fastener installation</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>C Proper storage for mechanical fasteners</td>
<td>Observe</td>
<td>Observe</td>
</tr>
</tbody>
</table>
Table D6.7-2  
Inspection or Execution Tasks  
During Mechanical Fastening

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>B</td>
<td>Observe</td>
<td>Observe</td>
</tr>
</tbody>
</table>

Table D6.7-3  
Inspection or Execution Tasks  
After Mechanical Fastening

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Perform</td>
<td>Perform</td>
</tr>
<tr>
<td>B</td>
<td>Perform</td>
<td>Perform</td>
</tr>
<tr>
<td>C</td>
<td>Not Required</td>
<td>Perform</td>
</tr>
</tbody>
</table>

1 Documentation tasks for quality control should be as defined by the applicable quality control program of the component manufacturer or installer.

D6.8 Inspection of Cold-Formed Steel Light-Frame Construction

D6.8.1 The component manufacturer’s quality control inspector shall perform inspections of the component assemblies to verify compliance with the details shown on the shop drawings.

D6.8.2 The installer’s quality control inspector shall perform inspections of the field-installed cold-formed steel structural members, component assemblies and connectors to verify compliance with the details shown on the installation drawings.

D6.8.3 The quality assurance inspector shall perform verifications and inspections, as applicable, to verify compliance with the construction documents.

D6.8.4 Inspection tasks shall be in accordance with Table D6.8-1.

Table D6.8-1  
Inspection or Execution Tasks  
After Installation of Cold-Formed Steel Light-Frame Construction

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Perform</td>
<td>Perform</td>
</tr>
<tr>
<td>B</td>
<td>Not Required</td>
<td>Perform</td>
</tr>
</tbody>
</table>

1 Documentation tasks for quality control should be as defined by the applicable quality control program of the component manufacturer or installer.

D6.9 Additional Requirements for Lateral Force-Resisting Systems

Additional inspection tasks for cold-formed steel lateral force-resisting systems shall be in accordance with Tables D6.9-1 through D6.9-5.

Exception: The requirements in Section D6.9 are not required for cold-formed steel lateral force-resisting systems where either of the following apply:

(a) The sheathing of the shear wall is gypsum board or fiberboard.
(b) The sheathing is wood structural sheathing or steel sheet sheathing on only one side of
the shear wall or diaphragm assembly and the fastener spacing of the sheathing is more than 4 inches (102 mm) on center (o.c.).

**D6.9.1 Fit-Up of Welds**

In Table D6.9-2, following performance of the inspection task for 10 welds made by a given welder, with the welder demonstrating understanding of requirements and possession of skills, the Perform designation of this task shall be reduced to Observe.

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Verify compliance of shear wall and diaphragm sheathing, diagonal strap bracing, and hold-downs</td>
<td>Perform</td>
<td>Perform</td>
</tr>
<tr>
<td>B Document acceptance or rejection of shear wall and diaphragm sheathing, diagonal strap bracing, and hold-downs</td>
<td>Not Required</td>
<td>Perform</td>
</tr>
</tbody>
</table>

1 Documentation tasks for quality control should be as defined by the applicable quality control program of the component manufacturer or installer.

**Table D6.9-2**

Additional Inspection or Execution Tasks
Prior to Welding of Cold-Formed Steel Lateral Force-Resisting Systems

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Welder identification system¹</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>B Fit-up of welds (alignment, gaps, condition of steel surfaces)</td>
<td>Perform/Observe²</td>
<td>Observe</td>
</tr>
</tbody>
</table>

1 A system maintained by the component manufacturer or installer, as applicable, by which a welder who has welded a joint or member can be identified.
2 See Section D6.9.1.

**Table D6.9-3**

Additional Inspection or Execution Tasks
Prior to Mechanical Fastening of Cold-Formed Steel Lateral Force-Resisting Systems

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Proper fasteners selected</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>B Proper installation procedure selected</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>C Connecting elements meet applicable requirements</td>
<td>Observe</td>
<td>Observe</td>
</tr>
</tbody>
</table>
Table D6.9-4
Additional Inspection or Execution Tasks
During Mechanical Fastening of Cold-Formed Steel Lateral Force-Resisting Systems

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>B</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>C</td>
<td>Perform</td>
<td>Perform</td>
</tr>
</tbody>
</table>

A For screw connections, joint brought tight (e.g., clamped) to avoid gaps between plies
B For screw connections, tool adjusted to avoid stripped and overdriven fasteners
C For post-installed connections to concrete, installation in accordance with manufacturer’s instructions

Table D6.9-5
Additional Inspection or Execution Tasks
After Installation of Cold-Formed Steel Lateral Force-Resisting Systems

<table>
<thead>
<tr>
<th>Task</th>
<th>QC</th>
<th>QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Perform</td>
<td>Perform</td>
</tr>
<tr>
<td>B</td>
<td>Not Required</td>
<td>Perform</td>
</tr>
</tbody>
</table>

A Verify compliance of cold-formed steel lateral force-resisting system installation
B Document acceptance or rejection of installation of cold-formed steel lateral force-resisting system

1 Documentation tasks for quality control should be as defined by the applicable quality control program of the component manufacturer or installer.

D7 Nonconforming Material and Workmanship

D7.1 Additional Inspections

In the event that observations determine that the materials and/or workmanship are not in conformance with the applicable documents, additional inspections, as specified by the quality control program or registered design professional, shall be performed to determine the extent of non-conformance.

D7.2 Rejection of Material

D7.2.1 Identification and rejection of materials and workmanship not in conformance with the construction documents is permitted at any time during progress of or following the completion of the work. However, this provision shall not relieve the owner or the inspector of the obligation for timely, in-sequence inspections.

D7.2.2 Nonconforming material and workmanship shall be brought to the immediate attention of the contractor and the installer.

D7.2.3 Nonconforming material or workmanship shall be brought into conformance, or made suitable for its intended purpose, as determined by the registered design professional.
E. TRUSSES

E1 General

Cold-formed steel trusses shall be designed in accordance with the requirements of this chapter, as applicable.

E1.1 Scope and Limits of Applicability

E1.1.1 Chapter E shall apply to design, manufacturing, quality criteria, installation and testing as they relate to the design of cold-formed steel trusses.

E1.1.2 The responsibilities specified in Section E2 are not intended to preclude alternate provisions as agreed upon by the parties involved.

E2 Truss Responsibilities

Truss responsibilities shall be in accordance with Section I1 of AISI S202.

E3 Loading

[Reserved]

E4 Truss Design

Except as modified or supplemented in this Standard, strength determinations shall be in accordance with AISI S100 [CSA S136].

E4.1 Materials

Sheet steel materials utilized in steel truss construction shall comply with ASTM A1003/A1003M Type H or ASTM A653/A653M Type SS, HSLAS, or HSLAS-F. Cold-formed steel welded tubing utilized in steel truss construction shall comply with ASTM A500.

E4.2 Corrosion Protection

Truss members, including gusset plates, shall have corrosion protection as required in accordance with Section A4.

E4.3 Analysis

In lieu of a rational engineering analysis to define joint flexibility, the following analysis modeling assumptions shall be used:

1. Chord members are continuous, except at the heel, pitch breaks, and chord splices where members are assumed to have pinned connections.

2. Web members are assumed to have pinned connections at each end.

Use of a specific joint stiffness other than the complete rotational freedom of a pin for a connection is permitted if the connection is designed for the forces resulting from a structural analysis with this specific joint stiffness.

E4.4 Member Design

E4.4.1 Properties of Sections

For C-shapes and other simple cross-section geometries, the properties of sections shall
be determined in accordance with conventional methods of structural design *rational engineering analysis*. Properties shall be based on full cross-section properties, except where use of a reduced cross-section or effective design width is required by AISI S100 [CSA S136]. For other cross-section geometries, properties shall be based on tests in accordance with Appendix 2.1.

**E4.4.2 Compression Chord Members**

The compression *chord member* shall be evaluated for axial *load* alone using Section C4 of AISI S100 [CSA S136], bending in accordance with Section C3.1 of AISI S100 [CSA S136], and combined axial *load* and bending in accordance with Section C5.2 of AISI S100 [CSA S136].

**E4.4.2.1** For axial *load* *strength* [resistance] determination, the effective length, KL, shall be determined by *rational engineering analysis*, testing, or the following design assumptions as applicable:

(a) For *C-shape chord members* with the x-axis as the axis of symmetry: Lₙ shall be equal to the distance between *panel points*, and Cₘ shall be taken as 0.85, unless an analysis is performed to justify another value. Where the chord member is continuous over at least one intermediate *panel point* and where sheathing is directly attached to the chord member, K.autoconfigure shall be taken as 0.75. Otherwise, K.autoconfigure shall be taken as unity. As an alternative, L_auto shall be the distance between points of contraflexure with C_auto and K.autoconfigure taken as unity. Where sheathing is attached to the chord member, L_auto shall be the distance between sheathing connectors and K.autoconfigure shall be taken as 0.75. Where purlins are attached to the chord member, L_auto shall be the distance between purlins with K.autoconfigure equal to unity. Lₜ shall be equal to the distance between *panel points*. Where the chord member is continuous over at least one intermediate *panel point* between the heel and *pitch break* and where sheathing is directly attached to the chord member, Kₜ shall be taken as 0.75. Otherwise, Kₜ shall be taken as unity. As an alternate, Lₜ shall be the distance between points of contraflexure with Kₜ taken as unity.

where

\[ Cₘ = \text{End moment coefficient in interaction formula} \]
\[ Kₜ = \text{Effective length factor for torsion} \]
\[ Kₓ = \text{Effective length factor for buckling about x-axis} \]
\[ Kᵧ = \text{Effective length factor for buckling about y-axis} \]
\[ Lₜ = \text{Unbraced length of compression member for torsion} \]
\[ Lₓ = \text{Unbraced length of compression member for bending about x-axis} \]
\[ Lᵧ = \text{Unbraced length of compression member for bending about y-axis} \]

(b) For *hat-shapes* with the x-axis as the axis of symmetry: Where sheathing is attached to the chord member, Lₓ shall be equal to the distance between sheathing connectors and Kₓ shall be taken as 0.75. Where purlins are attached to the chord member, Lₓ shall be the distance between purlins with Kₓ equal to unity. Lᵧ shall be equal to the distance between *panel points*, and Cₘ shall be taken as 0.85, unless an analysis is performed to justify another value. Where the chord member is continuous over at least one intermediate *panel point* and
where sheathing is directly attached to the chord member, \( K_y \) shall be taken as 0.75. Otherwise, \( K_y \) shall be taken as unity. As an alternative, \( L_y \) shall be the distance between points of contraflexure with \( C_m \) and \( K_y \) taken as unity. \( L_t \) shall be equal to the distance between sheathing connectors or purlin spacing. Where the chord member is continuous over at least one intermediate panel point between the heel and pitch break and where sheathing is directly attached to the chord member, \( K_t \) shall be taken as 0.75. Otherwise, \( K_t \) shall be taken as unity. As an alternate, \( L_t \) shall be the distance between the points of contraflexure with \( K_t \) taken as unity.

(c) For Z-shapes with the x-axis as out-of-the-plane of the truss: \( L_x \) shall be equal to the distance between panel points, and \( C_m \) shall be taken as 0.85, unless an analysis is performed to justify another value. Where the chord member is continuous over at least one intermediate panel point and where sheathing is directly attached to the chord member, \( K_x \) shall be taken as 0.75. Otherwise, \( K_x \) shall be taken as unity. As an alternative, \( L_x \) shall be the distance between points of contraflexure with \( C_m \) and \( K_x \) taken as unity. Where sheathing is attached to the chord member, \( L_y \) shall be equal to the distance between sheathing connectors and \( K_y \) shall be taken as 0.75. Where purlins are attached to the chord member, \( L_y \) shall be the distance between purlins with \( K_y \) equal to unity. Where the chord member depth is less than 6 inches, \( L_t \) shall be equal to the distance between sheathing connectors or purlin spacing. For Z-shapes where the chord member depth is greater than or equal to 6 inches, \( L_t \) shall be equal to the distance between panel points. Where the chord member is continuous over at least one intermediate panel point between the heel and pitch break and where sheathing is directly attached to the chord member, \( K_t \) shall be taken as 0.75. Otherwise, \( K_t \) shall be taken as unity. As an alternative, \( L_t \) shall be equal to the distance between points of contraflexure with \( K_t \) taken as unity.

**E4.4.2.2** For bending strength [resistance] determination, the effective length, \( K_L \), shall be determined by rational engineering analysis, testing, or the following design assumptions as applicable:

(a) Where sheathing is attached to the compression flange, \( M_n = S_c F_y \) in accordance with Section C3.1.1 of AISI S100 [CSA S136].

(b) Where purlins are attached to the compression flange between panel points, \( M_n = S_c F_c \) in accordance with Section C3.1.2.1 of AISI S100 [CSA S136] with \( K_L_y \) and \( K_L_t \) for C-shapes and Z-shapes determined in accordance with E4.4.2.1 and \( K_L_x \) and \( K_L_t \) for hat-shapes taken as the distance between purlins.

(c) Where sheathing or purlins are attached to the tension flange and the compression flange is laterally unbraced, \( M_n = S_c F_c \) in accordance with Section C3.1.2.1 of AISI S100 [CSA S136]. For continuous span chord members, \( M_n \) in the region of the panel point shall be determined with \( K_L_y \) and \( K_L_t \) for C-shapes and Z-shapes determined in accordance with E4.4.2.1 and \( K_L_x \) and \( K_L_t \) for hat-shapes taken as the distance between the panel point and the point of contraflexure, and \( C_p \) shall be taken as unity. For simple and continuous span chord members, \( M_n \) in the mid-span region shall be determined with the effective length taken as the
distance between panel points and $C_b$ shall be computed in accordance with Section C3.1.2.1 of AISI S100 [CSA S136].

where

$C_b$ = Bending coefficient dependent on moment gradient
$F_c$ = Critical buckling stress
$F_y$ = Yield strength used for design
$K_t$ = Effective length factor for torsion
$K_x$ = Effective length factor for buckling about x-axis
$K_y$ = Effective length factor for buckling about y-axis
$L_t$ = Unbraced length of compression member for torsion
$L_x$ = Unbraced length of compression member for bending about x-axis
$L_y$ = Unbraced length of compression member for bending about y-axis
$M_n$ = Nominal flexural strength [resistance]
$S_c$ = Elastic section modulus of effective section calculated relative to extreme compression fiber at $F_c$
$S_e$ = Elastic section modulus of effective section calculated relative to extreme compression fiber at $F_y$

**E4.4.2.3** When a C-shaped section compression chord member is subject to concentrated load at a panel point, the interaction of axial compression, bending and web crippling shall be determined in accordance with the following:

For ASD:

$$\frac{P}{P_{no}} + \frac{M}{M_{n xo}} + \frac{R}{R_{n}} \leq \frac{1.49}{\Omega}$$  \hfill (Eq. E4.4.2.3-1)

where

$P$ = Required compressive axial strength
$M_x$ = Required flexural strength
$R$ = Required concentrated load strength
$P_{no}$ = Nominal axial strength determined at $f = F_y$
$M_{n xo}$ = Nominal flexural strength determined at $f = F_y$
$R_{n}$ = Nominal interior one-flange web crippling strength
$\Omega$ = 1.95

For LRFD and LSD:

$$\frac{\overline{P}}{P_{no}} + \frac{\overline{M}_x}{M_{n xo}} + \frac{\overline{R}}{R_{n}} \leq 1.49\phi$$  \hfill (Eq. E4.4.2.3-2)

where

$\overline{P}$ = Required compressive axial strength [axial force of factored loads]
$\overline{M}_x$ = Required flexural strength [moment of factored loads]
$\overline{R}$ = Required concentrated load strength [factored concentrated load]
$P_{no}$ = Nominal axial strength [resistance] determined at $f = F_y$
$M_{n xo}$ = Nominal flexural strength [resistance] determined at $f = F_y$
$R_{n}$ = Nominal interior one-flange loading web crippling strength [resistance]
$\phi$ = 0.85 for LRFD
= 0.80 for LSD
**E4.4.3 Tension Chord Members**

The tension chord member shall be evaluated for axial load in accordance with Section C2 of AISI S100 [CSA S136], bending in accordance with Section C3.1 of AISI S100 [CSA S136], and combined axial load and bending in accordance with Section C5.1 of AISI S100 [CSA S136]. The axial load is permitted to be taken as acting through the centroid of the section.

**E4.4.4 Compression Web Members**

Compression web members shall be evaluated for axial load alone using Section C4 of AISI S100 [CSA S136] and combined axial load and bending using Section C5.2 of AISI S100 [CSA S136], and the requirements of this section, as applicable.

**E4.4.4.1** For a C-shaped compression web member that is attached at each end through its web element back-to-back with the web of a C-shaped chord member and is not subjected to applied loads between its ends, the interaction of axial compression and out-of-plane bending shall be determined in accordance with the following interaction equation:

For ASD:

$$\frac{\Omega_b \Omega_c C_{my} R_P e}{P_n M_{ny} \alpha_y} \leq 1.0 \quad (Eq. \ E4.4.4-1)$$

For LRFD and LSD:

$$\frac{R \bar{P}}{\phi_e P_n} + \frac{C_{my} \bar{R}_P e}{\phi_b M_{ny} \alpha_y} \leq 1.0 \quad (Eq. \ E4.4.4-2)$$

where

$$R = -\left(\frac{L/r}{173}\right)^2 + \frac{L/r}{88} - 0.22 \geq 0.6 \quad (Eq. \ E4.4.4-3)$$

$L$ = Unbraced length of the compression web member

$r$ = Radius of gyration of the full section about the minor axis

$P_n$ = Nominal axial strength [resistance] based on Section C4.1 of AISI S100 [CSA S136]. Only flexural buckling need be considered.

$e$ = Eccentricity of compression force with respect to the centroid of the full section of the web member

$P$, $\Omega_b$, $\Omega_c$, $C_{my}$, $M_{ny}$, $\bar{P}$, $\phi_e$, $\phi_b$ and $\alpha_y$ shall be as determined in accordance with Section C5.2.1 (ASD) or C5.2.2 (LRFD and LSD) of AISI S100 [CSA S136].

When computing the available strength [resistance], the effective lengths, $K_L \lambda \nu$, $K_y L_y$ and $K_L \lambda \nu$, shall be taken as the distance between the centers of the member’s end connection patterns.

**E4.4.4.2** For other compression web members that are concentrically loaded, the axial compression load is permitted to be taken as acting through the centroid of the section.

**E4.4.4.3** For other compression web members that are not concentrically loaded, proper regard for eccentricity shall be considered.

**E4.4.5 Tension Web Members**

Tension web members shall be evaluated for axial load in accordance with Section C2 of
AISI S100 [CSA S136]. For tension web members, which are symmetrically loaded, the axial tension load is permitted to be taken as acting through the centroid of the section. For other tension members that are not symmetrically loaded, proper regard for eccentricity shall be considered.

**E4.4.6 Eccentricity in Joints**

**E4.4.6.1** A rational engineering analysis using multiple nodes or an analysis using single node that includes proper regard for the effects of eccentricity shall be performed.

**E4.4.6.2** Chord member shear and moments in joints shall include the following considerations:

(a) Where the web member lap length is greater than or equal to 75% of the chord member depth, the chord member shall be investigated for combined bending and shear in accordance with Equation C3.3.1-2 (ASD) or Equation C3.3.2-2 (LRFD and LSD) of AISI S100 [CSA S136]. For C-shaped section trusses where screws are used as the connector, a minimum of four screws shall be used in the web member to chord member connection and the screws shall be uniformly distributed in the lapped area.

(b) Where the web member lap length is less than 75% of the chord member depth, the chord member shall be investigated for combined bending and shear in accordance with Equation C3.3.1-1 (ASD) or C3.3.2-1 (LRFD and LSD) of AISI S100 [CSA S136].

**E4.4.6.3** Along the length of the chord member, at the mid-point between the intersecting web members at a joint, shear shall be evaluated by Section C3.2 of AISI S100 [CSA S136]. The shear buckling coefficient shall be based on either Equation C3.2.1-6 or C3.2.1-7 with “a” taken as the smaller of the distance between the fastener groups, or center-to-center of the web members.

**E4.5 Gusset Plate Design**

**E4.5.1** The nominal axial compressive strength [resistance], $P_n$, of thin, flat gusset plates shall be calculated as follows:

$$P_n = R_g \cdot b \cdot t \cdot F_y$$

(Eq. E4.5-1)

where

$$R_g = \left(0.47 \frac{W_{\text{min}}}{L_{\text{eff}}} + 0.3\right)$$

where $\frac{W_{\text{min}}}{L_{\text{eff}}} \leq 1.5$ (Eq. E4.5-2)

$$= 1.0 \quad \text{where} \quad \frac{W_{\text{min}}}{L_{\text{eff}}} > 1.5$$

$b$ = Effective width determined in accordance with Section B2.1 of AISI S100 [CSA S136] with $f=F_y$, $k=4$ and $w=W_{\text{min}}$

$F_y$ = Specified minimum yield strength

$t$ = Design thickness of gusset plate

$\Omega_c$ = 2.50 for ASD

$\phi_c$ = 0.60 for LRFD

$= 0.50$ for LSD

$W_{\text{min}}$ shall be taken as the lesser of the actual gusset plate width or Whitmore section, which shall be determined using a spread-out angle of 30° along both sides of the
connection, beginning at the first row of fasteners in the connection. $L_{\text{eff}}$ shall be taken as the average length between the last rows of fasteners of adjacent truss members in the connection.

Equation E4.5-1 shall be valid for the range of parameters listed in Table E4.5-1.

<table>
<thead>
<tr>
<th>Table E4.5-1</th>
<th>Parameters for Equation E4.5-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Minimum</td>
</tr>
<tr>
<td>Gusset Plate:</td>
<td></td>
</tr>
<tr>
<td>Design Thickness</td>
<td>0.0566 inch (1.438 mm)</td>
</tr>
<tr>
<td>Design Yield Strength</td>
<td>33 ksi (228 MPa)</td>
</tr>
<tr>
<td>$W_{\text{min}} / L_{\text{eff}}$ Ratio</td>
<td>0.8</td>
</tr>
<tr>
<td>Chord Member-to-Gusset Plate Fastener Pattern</td>
<td>Two rows with two fasteners per row</td>
</tr>
</tbody>
</table>

E4.5.2 The nominal axial tensile strength [resistance] of thin, flat gusset plates shall be calculated in accordance with the requirements of Section C2 of AISI S100 [CSA S136].

E4.6 Connection Design

E4.6.1 Fastening Methods

Fastening systems shall be specified by the truss designer. Screw, bolt, and weld connections shall be designed in accordance with AISI S100 [CSA S136]. For connections using other fastener types, design values shall be determined by testing in accordance with Section F1 of AISI S100 [CSA S136].

Other fastening methods shall be in accordance with the manufacturer’s requirements.

E4.6.2 Coped Connections for C-Shaped Sections

E4.6.2.1 Coping is permitted at pitch break and heel connections in accordance with the truss design and the following, as applicable:

(a) At a coped heel connection with a coped flange and a bearing stiffener having a moment of inertia ($I_{\text{min}}$) greater than or equal to 0.161 in.$^4$ (67,000 mm$^4$), the available shear strength [factored resistance] shall be calculated in accordance with Section C3.2 of AISI S100 [CSA S136] and reduced by the following factor, R:

$$R = 0.976 - \frac{0.556c}{h} - \frac{0.532d_c}{h} \leq 1.0 \quad (Eq. \ E4.6.2-1)$$

where

- $c$ = Length of cope
- $d_c$ = Depth of cope
- $h$ = Flat width of web of section being coped
- $I_{\text{min}}$ = Moment of inertia determined with respect to an axis parallel to the web of the chord member
- $t$ = Design thickness of section being coped

(b) At a coped heel connection with a coped flange where a bearing stiffener having a moment of inertia ($I_{\text{min}}$) less than 0.161 in.$^4$ (67,000 mm$^4$), the strength at the heel
is governed by web crippling determined in accordance with Section C3.4 of AISI S100 [CSA S136] and reduced by the following factor, R:

\[
R = 1.036 - \frac{0.668c}{h} - \frac{0.0505d_c}{h} \leq 1.0 \quad \text{Eq. E4.6.2-2}
\]

**E4.6.2.2** Equations E4.6.2-1 and E4.6.2-2 shall be applicable within the following limitations:
- \( h/t \leq 200 \),
- \( 0.10 < c/h < 1.0 \), and
- \( 0.10 < d_c/h < 0.4 \)

**E4.7 Serviceability**

Serviceability requirements, as specified in AISI S100 [CSA S136], shall be determined by the building designer or applicable building code. When computing truss deflections, it is permitted to use the full cross-sectional area of the truss members.

**E5 Quality Criteria for Steel Trusses**

Section E5 applies to the manufacture of cold-formed steel trusses.

**E5.1 Manufacturing Quality Criteria**

The truss manufacturer shall manufacture the trusses in accordance with the final truss design drawings, using the quality criteria required by the manufacturer’s quality control program unless more stringent quality criteria are required by the owner in writing or through the construction documents.

**E5.2 Member Identification**

Truss chord members and web members shall be identified in accordance with the product identification requirements for framing members defined in Section A5.5.

**E5.3 Assembly**

**E5.3.1** Trusses shall have steel members that are accurately cut, in accordance with the truss design, so that the assembled truss is made by close-fitting steel members.

**E5.3.2** The maximum gap between web members shall not exceed 1/2 inch (12.7 mm) unless specified or accepted by the truss design engineer or truss designer.

**E5.3.3** The location of chord members, web members, and joints shall be as specified in the truss design.

**E5.3.4** Truss dimensions which vary from the truss design shall not exceed the tolerances shown in Table E5.8. Inaccuracies exceeding these allowable tolerances shall be acceptable upon approval and follow-up documentation by the truss design engineer or truss designer.

**E5.3.5** Any shop modifications or repairs shall be documented by the truss design engineer or truss designer.
Table E5.5-1
Manufacturing Tolerances for Finished Truss Units

<table>
<thead>
<tr>
<th>Length1</th>
<th>Variance from Design Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 30 feet (9.14 m)</td>
<td>½ inch (12.7 mm)</td>
</tr>
<tr>
<td>Over 30 feet (9.14 m)</td>
<td>¾ inch (19.1 mm)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Height2</th>
<th>Variance from Design Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 5 feet (1.52 m)</td>
<td>¼ inch (6.4 mm)</td>
</tr>
<tr>
<td>Over 5 feet (1.52 m)</td>
<td>½ inch (12.7 mm)</td>
</tr>
</tbody>
</table>

1 Length, for manufacturing tolerance purposes, is the overall length of the truss unit, excluding overhangs and extensions.

2 Height, for manufacturing tolerance purpose, is the overall height of the truss unit measured from the top of the top chord member to the bottom of the bottom chord member at the highest point of the truss, excluding projections above the top chord member and below the bottom chord member, overhangs, and extensions.

E6 Truss Installation

Section E6 applies to installation of cold-formed steel trusses.

E6.1 Installation Tolerances

E6.1.1 Straightness

Trusses shall not be installed with an overall bow or bow in any chord member or panel which exceeds the lesser of L/200 or 2 inches (50.8 mm), where L is the length of the truss, chord member, or panel in inches.

E6.1.2 Plumbness

Trusses shall not be installed with a variation from plumb (vertical tolerance) at any point along the length of the truss from top to bottom which exceeds 1/50 of the depth of the truss at that point or 2 inches (50.8 mm), whichever is less, unless trusses are specifically designed to be installed out of plumb.

E6.1.3 Top Chord Bearing Trusses

For top chord bearing trusses, a maximum gap tolerance between the inside of the bearing and the first diagonal or vertical web member shall be specified in the design.

E7 Test-Based Design

Tests, when required as defined below, shall be conducted under the supervision of a registered design professional in accordance with the following:

(a) For cold-formed steel truss components (chord members and web members) for which the nominal strength [resistance] cannot be determined in accordance with this Standard or its reference documents, performance tests shall be performed in accordance with Appendix 2.1.

(b) For cold-formed steel truss connections for which the nominal strength [resistance] cannot be determined in accordance with this Standard or its reference documents, performance tests shall be performed in accordance with AISI S905.

(c) For cold-formed steel trusses for which the nominal strength [resistance] can be determined in accordance with this Standard and its reference documents or determined on the basis of
component performance tests in accordance with Appendix 2.1, and when it must be demonstrated that the strength [resistance] is not less than the nominal strength [resistance] specified in this Standard or its reference documents, confirmatory tests shall be performed in accordance with Appendix 2.2.

(d) For cold-formed steel trusses for which the nominal strength [resistance] cannot be determined in accordance with this Standard and its reference documents or determined on the basis of component performance tests in accordance with Appendix 2.1, performance tests shall be performed in accordance with Appendix 2.3.
F. TESTING

F1 General

Tests, when required to determine the strength, flexibility or stiffness of cold-formed steel structural members or connections, shall be in accordance with approved test methods and Section F1 of AISI S100 [CSA S136], and shall be conducted under the supervision of a design professional.

The following test standards are permitted to be used to determine the strength, flexibility or stiffness of cold-formed steel structural members and connections via testing:

1. AISI S901, Rotational-Lateral Stiffness Test Method for Beam-to-Panel Assemblies
2. AISI S902, Stub-Column Test Method for Effective Area of Cold-Formed Steel Columns
3. AISI S903, Standard Methods for Determination of Uniform and Local Ductility
4. AISI S904, Standard Test Methods for Determining the Tensile and Shear Strength of Screws
5. AISI S905, Test Standard for Cold-Formed Steel Connections
6. AISI S907, Test Standard for Cantilever Test Method for Cold-Formed Steel Diaphragms
7. AISI S909, Standard Test Method for Determining the Web Crippling Strength of Cold-Formed Steel Beams
8. AISI S910, Test Method for Distortional Buckling of Cold-Formed Steel Hat-Shaped Compression Members
9. AISI S911, Method for Flexural Testing for Cold-Formed Steel Hat-Shaped Beams
10. AISI S913, Test Standard for Hold-Downs Attached to Cold-Formed Steel Structural Framing
11. AISI S914, Test Standard for Joist Connectors Attached to Cold-Formed Steel Structural Framing
12. AISI S915, Test Standard for Through-The-Web Punchout Cold-Formed Steel Wall Stud Bridging Connectors

F2 Truss Components and Assemblies

Tests of cold-formed steel truss components and assemblies, when required in Chapter E, shall be in accordance with Appendix 2 or other approved test methods and Section F1 of AISI S100 [CSA S136], and shall be conducted under the supervision of a design professional.
APPENDIX 1, CONTINUOUSLY BRACED DESIGN FOR DISTORTIONAL BUCKLING RESISTANCE

1.1 Calculation of the nominal distortional buckling strength [resistance] in flexure in accordance with Section C3.1.4 of AISI S100 [CSA S136] or Appendix 1 of AISI S100 [CSA S136] is permitted to utilize the restraint provided by structural sheathing attached to the compression flange of floor joists or ceiling joists through determination of the rotational stiffness provided to the bending member, $k_\phi$ of Eq. 1-1. It is also permitted to assume no rotational restraint exists, i.e., $k_\phi = 0$.

1.2 Calculation of the nominal distortional buckling strength [resistance] in compression in accordance with Section C4.2 of AISI S100 [CSA S136] or Appendix 1 of AISI S100 [CSA S136] is permitted to utilize the restraint provided by structural sheathing attached to both flanges of floor joists or ceiling joists through determination of the rotational stiffness provided to the bending member, $k_\phi$ of Eq. 1-1. It is also permitted to assume no rotational restraint exists, i.e., $k_\phi = 0$.

1.3 The rotational stiffness, $k_\phi$, shall be determined in accordance with the following:

\[
k_\phi = \left(1/k_{\phi w} + 1/k_{\phi c}\right)^{-1}
\]  
(Eq. 1-1)

where

\[
k_{\phi w} = \text{Sheathing rotational restraint}
\]

\[
= \frac{EI_w}{L_1} + \frac{EI_w}{L_2} \text{ for interior members (joists or rafters) with structural sheathing fastened on both sides} \quad \text{(Eq. 1-2)}
\]

\[
= \frac{EI_w}{L_1} \text{ for exterior members (joists or rafters) with structural sheathing fastened on one side} \quad \text{(Eq. 1-3)}
\]

where

\[
EI_w = \text{Sheathing bending rigidity}
\]

\[
= \text{Values as specified in Table 1-1(a) for plywood and OSB}
\]

\[
= \text{Values as specified in Table 1-1(b) for gypsum board permitted only for serviceability calculations in accordance with Section 1.1.3 of Appendix 1 of AISI S100}
\]

\[
L_1, L_2 = \text{One-half joist spacing to the first and second sides respectively, as illustrated in Figure 1-1}
\]

\[
k_{\phi c} = \text{Connection rotational restraint}
\]

\[
= \text{Values as specified in Table 1-2 for fasteners spaced 12 in. o.c. (305 mm) or closer}
\]
Table 1-1 (a)\(^{1,2}\)

Plywood and OSB Sheathing Bending Rigidity, EI\(_w\) (lbf-in\(^2\)/ft)

<table>
<thead>
<tr>
<th>Span Rating</th>
<th>Strength Parallel to Strength Axis</th>
<th>Stress Perpendicular to Strength Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plywood 3-ply</td>
<td>Plywood 4-ply</td>
</tr>
<tr>
<td>24/0</td>
<td>66,000</td>
<td>66,000</td>
</tr>
<tr>
<td>24/16</td>
<td>86,000</td>
<td>86,000</td>
</tr>
<tr>
<td>32/16</td>
<td>125,000</td>
<td>125,000</td>
</tr>
<tr>
<td>40/20</td>
<td>250,000</td>
<td>250,000</td>
</tr>
<tr>
<td>48/24</td>
<td>440,000</td>
<td>440,000</td>
</tr>
<tr>
<td>16oc</td>
<td>165,000</td>
<td>165,000</td>
</tr>
<tr>
<td>20oc</td>
<td>230,000</td>
<td>230,000</td>
</tr>
<tr>
<td>24oc</td>
<td>330,000</td>
<td>330,000</td>
</tr>
<tr>
<td>32oc</td>
<td>715,000</td>
<td>715,000</td>
</tr>
<tr>
<td>48oc</td>
<td>1,265,000</td>
<td>1,265,000</td>
</tr>
</tbody>
</table>

Note:
1. To convert to lbf-in\(^2\)/in., divide table values by 12.
   To convert to N-mm\(^2\)/m, multiply the table values by 9.415.
   To convert to N-mm\(^2\)/mm, multiply the table values by 9.415.
2. Plywood and OSB bending rigidity are obtained from APA.
Table 1-1(b)¹
Gypsum Board Bending Rigidity
Effective Stiffness (Typical Range), EIₜₗ

<table>
<thead>
<tr>
<th>Board Thickness (in.)</th>
<th>EI (Lb-in²/in) of width of width</th>
<th>(N-mm²/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 (12.7)</td>
<td>1500 to 4000</td>
<td>(220,000 to 580,000)</td>
</tr>
<tr>
<td>0.625 (15.9)</td>
<td>3000 to 8000</td>
<td>(440,000 to 1,160,000)</td>
</tr>
</tbody>
</table>

Note:
1. Gypsum board bending rigidity is obtained from the Gypsum Association.

Table 1-2¹
Connection Rotational Restraint

<table>
<thead>
<tr>
<th>t (mils)</th>
<th>t (in.)</th>
<th>kₜₜ</th>
<th>kₜc</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>0.018</td>
<td>78</td>
<td>348</td>
</tr>
<tr>
<td>27</td>
<td>0.027</td>
<td>83</td>
<td>367</td>
</tr>
<tr>
<td>30</td>
<td>0.03</td>
<td>84</td>
<td>375</td>
</tr>
<tr>
<td>33</td>
<td>0.033</td>
<td>86</td>
<td>384</td>
</tr>
<tr>
<td>43</td>
<td>0.043</td>
<td>94</td>
<td>419</td>
</tr>
<tr>
<td>54</td>
<td>0.054</td>
<td>105</td>
<td>468</td>
</tr>
<tr>
<td>68</td>
<td>0.068</td>
<td>123</td>
<td>546</td>
</tr>
<tr>
<td>97</td>
<td>0.097</td>
<td>172</td>
<td>766</td>
</tr>
</tbody>
</table>

Note:
1. Fasteners spaced 12 in. (25.4 mm) o.c. or less.

Figure 1-1 Illustration of L₁ and L₂ for Sheathing Rotational Restraint
APPENDIX 2, TEST METHODS FOR TRUSS COMPONENTS AND ASSEMBLIES

2.1 Component Structural Performance Load Test

2.1.1 Flexural Test

Flexural tests shall be performed to determine the positive or negative flexural strength [resistance] of the cross-section of a truss member for static load.

2.1.1.1 Number of Test Specimens

The minimum number of test specimens shall be in accordance with Section F1 of AISI S100 [CSA S136].

2.1.1.2 Materials

The test specimens shall be representative of those intended for use in the final product. Mechanical properties of the steel shall be determined in accordance with Section F3 of AISI S100 [CSA S136].

2.1.1.3 Test Apparatus

The test apparatus and procedures employed shall produce a failure consistent with the purpose.

2.1.1.4 Load and Deflection Measuring Devices

The load measuring device or devices used shall be capable of measuring loads to an accuracy of ±2% of the ultimate load.

The deflection measuring devices, if employed, shall avoid magnification of deflection readings due to a movement of supports during loading. When deflection measuring systems that do not compensate for support settlement are used, measurement of support displacement under load shall be required in order to obtain an accurate load-deflection response. Deflection readings and measuring devices shall have an accuracy of 0.01 inches (0.25 mm).

2.1.1.5 Loading Procedures

Load shall be applied and load measurements shall be taken. The maximum loading rate shall not exceed a corresponding applied stress rate of 3 ksi (20.7 MPa) of gross cross-sectional area per minute.

2.1.1.6 Interpretation of Test Results

Evaluation of the test results shall be made in accordance with Section F1 of AISI S100 [CSA S136].

2.1.1.7 Report

The test report shall include a description of the test specimen with drawings detailing all pertinent dimensions. The description shall define the size, geometric type, and strength of all test specimen components. Pertinent connector information shall include type and size.

The measured mechanical properties (base steel thickness, yield stress, tensile strength
and percent elongation) of the tested specimens shall be included.

The documentation shall include details of the test setup, load application, deflection measurement locations, and drawings illustrating the test fixture.

The test report shall include the ultimate load, description of the failure mode(s), and load-deflection curves (or the load-deflection measurements).

The report shall include certification that the test program was performed under the direction of a registered design professional.

2.1.2 Compression Test

Compression tests shall be performed to define the compressive strength [resistance], excluding overall buckling, of a truss member for static load in accordance with AISI S902. Alternative tests methods shall be permitted, when accepted by the truss designer.

2.2 Full-Scale Confirmatory Load Test

2.2.1 Test Specimen

For the purpose of this test, a test specimen shall consist of a full-scale truss assembly representative of those intended for use in the final product.

2.2.2 Number of Test Specimens

A single confirmatory load test shall meet the required minimum number of test specimens.

2.2.3 Materials

The materials contained within the test specimen shall be representative of those intended for use in the final product. Mechanical properties of the steel shall be determined in accordance with Section F3 of AISI S100 [CSA S136].

2.2.4 Fabrication

Fabrication of the test specimen shall be representative of that intended for the finished product.

2.2.5 Test Apparatus

A test shall consist of a single truss, pair of trusses, or multiple trusses.

A single truss shall be tested in either a vertical position (normal or inverted) or in a horizontal position. A pair of trusses or multiple trusses shall be tested in a vertical position (normal or inverted).

The self-weight of the truss shall be included in the total load applied to trusses that are tested in a vertical position to compensate for the effect of dead loads and gravity.

Reaction supports shall provide clearance above the ground or restraining frame to allow for normal displacements, ease of loading, instrumentation, and provide room for observations and measurements. Supports shall have strength and stiffness to resist deformations during tests.

Support reaction hardware shall be typical of that planned for use in the completed structure or as required to satisfy the intent of the tests.

Lateral support shall be provided beneath a single truss when tested horizontally to keep
the test truss flat and to minimize any adverse lateral displacement caused by gravity. Lateral support shall be provided for single, paired, or multiple trusses when tested vertically to minimize adverse lateral displacement and prevent buckling of the assembly. Where lateral support is used, it shall not interfere with the free in-plane displacement of the truss or truss assembly. The components of the test truss shall not be laterally supported in a manner that will exceed that intended in a representative installation.

When loads are applied using dead weight, such as sand, masonry units, or water, the dead load material shall be positioned to prevent arching action.

When loads are applied using water, the water shall be compartmentalized into cells to prevent a non-uniform load as the truss deflects.

### 2.2.6 Load and Deflection Measuring Devices

The load measuring device or devices used shall be capable of measuring loads to an accuracy of ±2% of the ultimate load. When multiple trusses are tested as an assembly, load-measuring devices shall be located beneath each truss support.

The deflection measuring devices, if employed, shall avoid magnification of deflection readings due to a movement of supports during loading. When deflection-measuring systems that do not compensate for support settlement are used, measurement of support displacement under load shall be required in order to obtain an accurate load-deflection response. Deflection readings and measuring devices shall have an accuracy of 0.01 inches (0.25 mm).

### 2.2.7 Loading Procedures

Loading of the test specimens shall be achieved either using an incremental loading or a continuous loading method.

#### 2.2.7.1 Tests to Confirm Deflection

When a test to confirm deflection is required, the test load shall be applied up to the maximum load for deflection limit, at which time deflections shall be measured. When loading incrementally, each of the increments of test load shall not exceed 1/5 of the maximum load. When using continuous loading, the applied load shall be increased uniformly until the maximum load is reached.

When testing trusses in pairs, the deflections of two trusses at corresponding locations are permitted to be averaged. Support displacement under load shall be measured to obtain an accurate load-deflection response when deflection-measuring systems that do not compensate for support settlement are used.

#### 2.2.7.2 Tests to Confirm Available Strength [Factored Resistance] Assumptions

When a test to confirm available strength [factored resistance] is required, the test load shall be applied up to the design load times 1.65 for ASD and the design [factored] load for LRFD [LSD]. When loading incrementally, each of the increments of test load shall not exceed 1/5 of the design load times 1.65 for ASD and the design [factored] load for LRFD [LSD]. When using continuous loading, the applied load shall be increased uniformly until the design load times 1.65 ASD or the design [factored] load for LRFD [LSD] is reached. This load shall be held for not less than 5 minutes, and then the confirmatory test shall be considered complete.
2.2.8 Interpretation of Test Results

The confirmatory test shall be deemed successful if the test specimen complies with the loading requirements in Section 2.2.7. When a test to confirm design deflections is required, the test shall be deemed successful if the measured deflections of the test specimen do not exceed the design (dead plus live load) deflection limit.

2.2.9 Report

The test report shall include a description of the test specimen configuration with drawings detailing all pertinent dimensions. The description shall define the size, geometric type, and strength of all test specimen components. Pertinent connector information shall include type and size.

The measured mechanical properties (including base steel thickness, yield stress, tensile strength and percent elongation) of the tested specimens shall be included.

The documentation shall include details of the test setup, load application, deflection measurement locations, and drawings illustrating the test fixture.

The test report shall include the ultimate load, description of the failure mode(s), and load-deflection curves (or the load-deflection measurements).

The report shall include certification that the test program was performed under the direction of a registered design professional.

2.3 Full-Scale Structural Performance Load Test

2.3.1 Test Specimen

For the purpose of this test, a test specimen shall consist of a full-scale truss assembly representative of those intended for use in the final product.

2.3.2 Number of Test Specimens

The minimum number of test specimens shall be in accordance with Section F1 of AISI S100 [CSA S136].

2.3.3 Materials

The materials contained within the test specimen shall be representative of those intended for use in the final product. Mechanical properties of the steel shall be determined in accordance with Section F3 of AISI S100 [CSA S136].

2.3.4 Fabrication

Fabrication of the test specimen shall be representative of that intended for the finished product.

2.3.5 Test Apparatus

A test shall consist of a single truss, pair of trusses or multiple trusses.

A single truss shall be tested in either a vertical position (normal or inverted) or in a horizontal position. A pair of trusses or multiple trusses shall be tested in a vertical position (normal or inverted).

The self-weight of the truss shall be included in the total load applied to trusses that are tested in a vertical position to compensate for the effect of dead loads and gravity.
Reaction supports shall provide clearance above the ground or restraining frame to allow for displacements, loading, instrumentation, and provide room for observations and measurements. Supports shall have strength and stiffness to resist deformations during tests.

Support reaction hardware shall be typical of that planned for use in the completed structure or as required to satisfy the intent of the tests.

Lateral support shall be provided beneath a single truss when tested horizontally to keep the test truss flat and to minimize any adverse lateral displacement caused by gravity. Lateral support shall be provided for single, paired or multiple trusses when tested vertically to minimize adverse lateral displacement and prevent buckling of the assembly. Where lateral support is used, it shall not interfere with the free in-plane displacement of the truss or truss assembly. The components of the test truss shall not be laterally supported in a manner that will exceed that intended in a representative installation.

When loads are applied using dead weight, such as sand, masonry units, or water, the dead load material shall be positioned to prevent arching action.

When loads are applied using water, the water shall be compartmentalized into cells to prevent a non-uniform load as the truss deflects.

### 2.3.6 Load and Deflection Measuring Devices

When multiple trusses are tested as an assembly, load-measuring devices shall be located beneath each truss support. The load measuring device or devices used shall be capable of measuring loads to an accuracy of ±2% of the ultimate load.

The deflection measuring devices, if employed, shall avoid magnification of deflection readings due to a movement of supports during loading. When deflection-measuring systems that do not compensate for support settlement are used, measurement of support displacement under load shall be required in order to obtain an accurate load-deflection response. Deflection readings and measuring devices shall have an accuracy of 0.01 inches (0.25 mm).

### 2.3.7 Loading Procedures

Loading of the test specimens shall be achieved using either an incremental or a continuous loading method.

When loading incrementally, each of the increments of test load shall not exceed 1/5 of the estimated ultimate load. If structural failure has not occurred at the estimated ultimate load, additional load is to be applied in the same increments until failure occurs.

When using continuous loading, the applied load shall be increased uniformly until structural failure occurs.

Deflection readings shall be recorded at each load increment or continuously. When testing trusses in pairs, the deflections of two trusses at corresponding locations are permitted to be averaged. Support displacement under load shall be measured to obtain an accurate load-deflection response when deflection-measuring systems that do not compensate for support settlement are used.

For incremental loading, the ultimate load shall be the load level before failure. For continuous loading, the ultimate load shall be the load at failure.

### 2.3.8 Interpretation of Test Results

The performance test is permitted to be used to determine the available strength [factored
resistance] for the truss. For ASD, the available strength of the truss shall be the nominal strength divided by the safety factor; and for LRFD [LSD], the available strength [factored resistance] of the truss shall be the nominal strength [resistance] multiplied by the resistance factor. The nominal strength [resistance] of the truss is permitted to be taken as the average of the ultimate loads of the tested specimens. The resistance factor or safety factor for the performance test shall be determined in accordance with Section F1 of AISI S100 [CSA S136].

2.3.9 Report

The test report shall include a description of the test specimen configuration with drawings detailing all pertinent dimensions. The description shall define the size, geometric type, and strength of all test specimen components. Pertinent connector information shall include type and size.

The measured mechanical properties (including base steel thickness, yield stress, tensile strength and percent elongation) of the tested specimens shall be included.

The documentation shall include details of the test setup, load application, deflection measurement locations, and drawings illustrating the test fixture.

The test report shall include the ultimate load, description of the failure mode(s), and load-deflection curves (or the load-deflection measurements).

The report shall include certification that the test program was performed under the direction of a registered design professional.
AISI STANDARD

Commentary on the
North American Standard for
Cold-Formed Steel
Structural Framing

2015 Edition
DISCLAIMER

The material contained herein has been developed by the American Iron and Steel Institute (AISI) Committee on Framing Standards. The Committee has made a diligent effort to present accurate, reliable, and useful information on cold-formed steel framing design and installation. The Committee acknowledges and is grateful for the contributions of the numerous researchers, engineers, and others who have contributed to the body of knowledge on the subject. Specific references are included in this Commentary.

With anticipated improvements in understanding of the behavior of cold-formed steel framing and the continuing development of new technology, this material will become dated. It is anticipated that AISI will publish updates of this material as new information becomes available, but this cannot be guaranteed.

The materials set forth herein are for general purposes only. They are not a substitute for competent professional advice. Application of this information to a specific project should be reviewed by a design professional. Indeed, in many jurisdictions, such review is required by law. Anyone making use of the information set forth herein does so at their own risk and assumes any and all liability arising therefrom.
PREFACE

This *Commentary* is intended to facilitate the use and provide an understanding of the background of AISI S240, *North American Standard for Cold-Formed Steel Structural Framing*. The *Commentary* illustrates the substance and limitations of the various provisions of the Standard.

In the *Commentary*, sections are identified by the same notation as used in the Standard. Words that are italicized are defined in AISI S240. Terms included in square brackets are specific to *Limit States Design* terminology.
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COMMENTARY ON THE
NORTH AMERICAN STANDARD FOR
COLD-FORMED STEEL STRUCTURAL FRAMING

A. GENERAL

In 2015, the following AISI cold-formed steel framing standards were consolidated into a single standard, AISI S240 (AISI, 2015a):

- AISI S200, North American Standard for Cold-Formed Steel Framing – General Provisions (AISI, 2012b)
- AISI S210, North American Standard for Cold-Formed Steel Framing – Floor and Roof System Design (AISI, 2012d)
- AISI S211, North American Standard for Cold-Formed Steel Framing – Wall Stud Design (AISI, 2012e)
- AISI S212, North American Standard for Cold-Formed Steel Framing – Header Design (AISI, 2012f)
- AISI S213, North American Standard for Cold-Formed Steel Framing – Lateral Design (AISI, 2012g)
- AISI S214, North American Standard for Cold-Formed Steel Framing – Truss Design (AISI, 2012i)

In 2015, AISI S400, North American Standard for Seismic Design of Cold-Formed Steel Structural Systems (AISI, 2015b) was developed. Modifications were made to align the provisions of AISI S240 with AISI S400, as follows:

- The applicability of AISI S240 for seismic design was limited to applications where specific seismic detailing is not required.
- Definitions no longer needed in AISI S240 were removed and remaining definitions were revised, if needed, for consistency with AISI S400.
- Seismic-specific tables for nominal shear strength [resistance] were deleted.
- Seismic-specific safety factors and resistance factors were deleted.
- Other seismic-specific requirements were removed, as appropriate, and remaining requirements were generalized for applicability to wind, seismic or other lateral loads.

A1 Scope

AISI S240 applies to the design and installation of structural members utilized in cold-formed steel light-frame construction applications and other structures. It applies to floor, wall and roof systems, lateral force-resisting systems and trusses. However, cold-formed steel structural members and connections in seismic force-resisting systems must be designed in accordance with the additional provisions of AISI S400 where increased seismic performance is required.

The Standard is intended to serve as a supplement to AISI S100 [CSA S136] (AISI, 2012a; CSA, 2012).

Design provisions related to nonstructural members can be found in AISI S220, North American Standard for Cold-Formed Steel Framing-Nonstructural Members (AISI, 2011b). However, the use of AISI S240 for the design of nonstructural members is permitted, since the requirements specified in AISI S240 for structural members are equivalent or more stringent than the requirements specified in AISI S220 for nonstructural members.

In 2015, the provision that the Standard applies to applications where the specified minimum base steel thickness is not greater than 0.1180 inches (2.997 mm) was replaced with the
provision that the Standard applies to light-frame construction applications, and a definition for the term light-frame construction was added to the Standard. Cold-formed steel structural members for light-frame construction applications are available in a variety of thicknesses. Standard thicknesses for cold-formed steel structural members are defined in AISI S201 (AISI, 2012c).

A2 Definitions

A2.1 Terms

Codes and standards by their nature are technical, and as such specific words and phrases can change the intent of the provisions if not properly defined. As a result, it is necessary to establish a common platform by clearly stating the meaning of specific terms for the purpose of this Standard and other standards that reference it.

In the Standard, blocking is defined to transfer shear force or stabilize members. Figures C-A2-1 and C-A2-2 show examples of how track or stud members are used as blocking in various assemblies.
Figure C-A2-1 Application of Stud Track Blocking

Figure C-A2-2 Application of Joist Blocking
A3 Material

The sheet steel approved for use with this Standard for structural members must comply with ASTM A1003/A1003M (ASTM, 2015), except where specifically noted otherwise. ASTM A1003/1003M covers the chemical, mechanical and coating requirements for steel sheet used in the manufacture of cold-formed steel framing members such as studs, joists, and tracks.

ASTM A1003/1003M is a standard that was developed in order to incorporate requirements for metallic-coated, painted metallic-coated, or painted nonmetallic-coated steel sheet used for cold-formed steel framing members into a single standard. Mechanical properties defined in ASTM A1003/A1003M are minimum requirements. For example, the minimum yield strength of Type H or L 33 [NS230] steel is 33 ksi [230 MPa]; material with higher yield strength is permitted, but 33 ksi [230 MPa] is the design yield strength. Additionally, according to the ASTM A1003/1003M standard, Structural Grade Types H and L steel are intended for structural members and nonstructural Grade Type NS steel is intended for nonstructural members. It is noted that additional country-specific limitations for curtain wall studs are provided in AISI S100 [CSA S136], Section A2.3.1a, Appendix A or B.

A4 Corrosion Protection

The minimum coating designations listed in Standard Table A4-1 assume normal exposure and construction practices. Other types of coatings that provide equal or better corrosion protection may also be acceptable. When more severe exposure conditions are probable, consideration should be given to specifying heavier coating weight [mass].

The minimum coating specified by this Standard assumes normal exposure conditions that are defined as having the framing members enclosed within a building envelope or wall assembly within a controlled environment. When more severe exposure conditions are probable, such as industrial atmospheres and marine atmospheres, consideration should be given to specifying a heavier coating. Coating is specified by weight or mass.

This Standard does not require the edges of metallic-coated cold-formed steel framing members (shop or field cut in accordance with Standard Section C2.2, punched or drilled) to be touched up with zinc-rich paint, which is able to galvanically protect steel. When base steel is exposed, such as at a cut or scratch, the steel is cathodically protected by the sacrificial corrosion of the zinc coating, because zinc is more electronegative (more reactive) than steel in the galvanic series. A zinc coating will not be undercut because the steel cannot corrode when adjacent to the zinc coating. Therefore, any exposure of the underlying steel at an edge or scratch will not result in corrosion of the steel away from the edge or scratch and thus will not affect the performance of the coating or the steel structure (CFSEI, 2007a).

It is noted that ASTM A1004/A1004M (ASTM, 2014b) covers procedures for establishing the acceptability of steel sheet for use as cold-formed steel framing members. This practice is to be used to assess the corrosion resistance of different coatings on steel sheet in a laboratory test. It is not intended to be used as an application performance standard for the cold-formed steel framing, but is to be used to evaluate coatings under consideration for addition to ASTM A1003/A1003M (ASTM, 2015).

Direct contact with dissimilar metals (e.g., copper, brass, etc.) should be avoided in order to prevent unwanted galvanic action from occurring. Methods for preventing the contact from occurring may be through the use of nonconductive and noncorrosive grommets at web penetrations or through the use of non-metallic brackets (a.k.a. isolators) fastened to hold the dissimilar metal building products (e.g. piping) away from the cold-formed steel framing. In 2006, a change was made to this Standard allowing the use of dissimilar metals in contact with cold-
formed steel framing, provided the specific application is approved. It was recognized that dissimilar metals in contact with cold-formed steel framing might not always be a problem. For example, there are no galvanic concerns where there is no moisture. A special case of dissimilar metals occurs in Canada where, for certain climatic conditions and building heights, the use of stainless steel brick ties is required. When these ties are connected to steel stud backup, contact between dissimilar metals can occur. For guidance on this dissimilar metals issue, refer to the Canadian standard CAN/CSA-A370-14, Connectors for Masonry (CSA, 2014).

When there is direct contact of cold-formed steel framing with pressure-treated wood, the treated wood, cold-formed steel framing, connector and/or fastener manufacturers should be contacted for recommendations. Methods that should be considered may include specifying a less corrosive pressure treatment (sodium borate, organic preservative systems, etc.), isolating the cold-formed steel and wood components, or changing details to avoid use of pressure-treated wood altogether.

Design professionals should take into account both the initial contact with wet or damp building materials, as well as the potential for those materials to absorb water during the building’s life, as both circumstances may accelerate corrosion.

In 2007, the Cold-Formed Steel Engineers Institute updated the 2004 AISI document, entitled Durability of Cold-Formed Steel Framing Members (CFSEI, 2007a), to give engineers, architects, builders and homeowners a better understanding of how galvanizing (zinc and zinc alloy coatings) provides long-term corrosion protection to cold-formed steel framing members. Additional information can be obtained from the American Galvanizers Association publication entitled Hot Dip Galvanizing For Corrosion Protection – A Specifier’s Guide (AGA, 2012) and the Cold-Formed Steel Engineers Institute’s publication entitled Corrosion Protection for Cold-Formed Steel Framing in Coastal Areas (CFSEI, 2007b).

A5 Products

AISI S100 [CSA S136], (AISI, 2012a; CSA, 2012) permits the minimum delivered base steel thickness (exclusive of any coatings) of a cold-formed steel member to be 95% of the design thickness. This Standard, therefore, specifies the minimum base steel thickness that complies with AISI S100 [CSA S136]. The thickness designations are consistent with standard industry practice, as published in AISI S201 (AISI, 2012c). It is recommended that thickness measurements be taken in the middle of the flat of the flange or web of the cross-section.

Section A5.3 has adopted a standard designator system for identifying cold-formed steel framing members. The intent for using a standard designator system was to overcome the varied designators that were produced by each individual manufacturer. In addition, the designator is used to identify not only a specific cold-formed steel framing member, but also to identify the section properties of that same member through the use of the manufacturer’s product technical information documents.
The following presents an example of the standard designator for a cold-formed steel stud:

350S162-33 represents a member with the following:

350 for 3.50 inch (89.9 mm) web depth

S for stud or joist

162 for 1.625 inch (41.3 mm) flange width

33 for 33 mil (0.0329 inch) (0.836 mm) designation thickness

In 2011, as part of an exercise to synchronize all relevant codes and specifications, the minimum tolerances for the manufacture of cold-formed steel framing members were included in the AISI framing standards. The minimum tolerances for the manufacture of structural members can be found in Section A5.4. In 2014, manufacturing tolerances for stiffening lip length and flange width were also added. The revisions are consistent with ASTM C955 (ASTM, 2011c). The minimum tolerances for the manufacture of nonstructural members can be found in AISI S220 (AISI, 2015). The manufacturing tolerances for length, web width, camber, bow, twist, etc. of framing members are consistent with ASTM C955, ASTM C645 (ASTM, 2011b), and manufacturers' certification programs.

To aid in shop and field verification, all framing members are to carry a product identification to indicate conformance with the minimum base steel thickness, coating designation, minimum yield strength, and manufacturer’s name.

In 2011, color coding of individual framing members or groups of like members were removed from the AISI framing standards with consideration that the color coding approach could cause confusion in differentiating between structural and nonstructural members of the same thickness. Further, color coding is optional and the criterion, if needed, exists in a non-mandatory Appendix of ASTM C645.

A5.2 Minimum Flange Width

In 2012, as part of an exercise to synchronize all relevant codes and specifications, the provisions for minimum flange width were added to the AISI framing standards, and were consistent with ASTM C645 (ASTM, 2011b) and ASTM C955 (ASTM, 2011c). The minimum flange width for C-shape members was included in the Standard to accommodate a butt joint of sheathing. The minimum flange width for track members was included in the Standard to accommodate an edge joint of sheathing.
B DESIGN

B1 General

B1.1 Loads and Load Combinations

Currently, ASCE 7 (ASCE, 2013) has no geographical-based information on Mexico. Therefore, users with projects in Mexico should work with the appropriate authority having jurisdiction to determine appropriate loads and load combinations that are consistent with the assumptions and rationale used by ASCE 7.

In 2009, the words “with no axial loads” were deleted to clarify that the intent is to evaluate deflections for bending of the wall stud alone when subjected to the Components and Cladding (C&C) wind loads.

B1.1.1 Live Load Reduction on Wall Studs

Since some building codes allow designers to reduce floor live load as a function of area of floor supported by gravity load-bearing members, a requirement was added in 2009 to clarify appropriate application of area live load reduction for the design of individual structural members in load-bearing wall framing, including vertical members such as studs or columns and horizontal members such as headers or beams within a wall assembly. The floor area (from one or more floors) contributing load to a wall framing member should be determined in a manner consistent with engineering mechanics.

B1.1.2 Wind Loading Considerations in the United States and Mexico

Because a wall stud subject to combined bending and axial load resists wind loads imposed on two surfaces, the member can be analyzed based on Main Wind Force Resisting System (MWFRS) wind loads. For bending alone, the wall stud experiences wind from only one surface and therefore must be analyzed for Components and Cladding (C&C) wind loads.

Section 1609.6.2.3 of the International Building Code (ICC, 2003) states that:

“Members that act as both part of the main force resisting system and as components and cladding shall be designed for each separate load case.”

Discussion in the Southern Standard Building Code Commentary (SBCCI, 1999) sheds light on a reasonable approach to the design of wall studs for wind resistance, stating that:

“Some elements of a building will function as part of the main wind force resisting system and components and cladding also. Such members include but not limited to roof panels, rafters, and wall studs. These elements are required to be designed using the loads that would occur by considering the element as part main wind force resisting system, and also separately checked or designed for loads that would occur by considering the element as component and cladding. The use of this section can be demonstrated by considering, for example, the design of a wall stud. When designing the stud for main wind force resisting system loads, all loads such as bending from the lateral force with the wind on the wall in addition to any uplift in combinations with the dead load of the roof or a story above induced by the simultaneous action of roof forces should be considered together. When designing the stud for component and cladding loads, only the bending resulting from the wind force normal to the stud and the dead load associated with that member should be considered. The member should be sized according to the more critical loading condition.”
The wood industry has also investigated this condition and has adopted a similar policy as shown in the Wood Frame Construction Manual (AFPA, 1995), where Section 2.4 states that:

“Studs tables are based upon bending stresses induces by C&C Loads. The bending stresses are computed independent of axial stresses. In addition, the case in which bending stresses from MWFRS loads act in combination with axial stresses from wind and gravity loads have been analyzed. For buildings limited to the conditions in the WFCM-SBC, the C&C loads control stud design.”

The commentary to Appendix C of ASCE 7 (ASCE, 2006) provides some guidance on the selection of loads for checking the serviceability limit state of buildings and their components, where Section B1.2 states in part:

“Use of factored wind load in checking serviceability is excessively conservative. The load combination with an annual probability of 0.05 of being exceeded, which can be used in checking short-term effects, is $D + 0.5L + 0.7W$.”

Thus, using 70% of the wind load from Components and Cladding for checking deflections should conservatively satisfy the above. In 2012, IBC Table 1604.3, Footnote f recommended that 42% of the wind load be used for checking deflections. The 2012 IBC is based on ASCE 7-10 and the ASD wind load factor of 0.6W is used to arrive at a service load pressure; thus, $0.7 \times 0.6 = 0.42$.

AISC Design Guide No. 3 (Fisher and West, 1990) also recommends reduced wind loads when checking the serviceability of cladding based upon a 10-year return period or 75 percent of the 50-year wind pressure.

**B1.2 Design Basis**

The strength determinations required by this Standard are to be in accordance with AISI S100 [CSA S136], (AISI, 2012a; CSA, 2012). For design guidance on the application of AISI S100 [CSA S136] to typical cold-formed steel construction, refer to Design Guide for Cold-Formed Steel Framing (AISI, 2007b) and Cold-Formed Steel Design (Yu and LaBoube, 2010).

**B1.2.1 Floor Joists, Ceiling Joists and Roof Rafters**

The Standard permits the design of floor joists, ceiling joists and roof rafters to be based on either a discretely braced design in which discrete braces are provided along the member’s length, or based on a continuously braced design in which attached sheathing or deck are attached in accordance with the Standard.

The continuously braced design provisions of the Standard are limited to floor joists, ceiling joists and roof rafters with dimensions and properties that are within the range of standard products, as defined by AISI S201 (AISI, 2012c). This limitation was deemed appropriate due to the availability of research and field experience with such members.

**B1.2.2 Wall Studs**

The 2007 edition of AISI S100 (AISI, 2007a) added new design provisions for considering distortional buckling of cold-formed steel members in bending (Section C3.1.4 of AISI S100) and compression (Section C4.2 of AISI S100). Commentary to AISI S100 provides detailed technical information on distortional buckling. In 2009, distortional buckling was introduced in this Standard, and separate provisions provided for discretely braced design and continuously braced design. Discrete braces must restrict rotation at the web/flange juncture. This may be accomplished with sufficiently stiff blocking to restrict...
rotations in the web, with strap across a series of members lacing from compression flange of one member to the tension flange of the next member and continuing, or with other systems – engineering judgment is required. Provisions for continuously braced design for distortional buckling are provided in Section B2.6.

The Standard permits the design of wall studs to be based on either an all steel design in which discrete braces are provided along the member’s length, or based on a sheathing braced design. Because load-bearing wall studs used in multi-story construction may go unsheathed for an extended period of time during construction, it is uncommon to use a sheathing braced design approach. It is permitted by this Standard to use sheathing attached to both flanges, or to use a combination of sheathing attached to one flange and discrete bracing stabilizing the other flange. When the curtain wall stud has sheathing only on one flange and discrete bracing on the other, the nominal flexural strength [resistance] is determined using the provisions of AISI S100 Section C3.1. When sheathing is attached to the compression flange, the lateral-torsional buckling does not need to be considered. Otherwise, the lateral-torsional buckling should be considered in accordance with AISI S100 Section C3.1.2. Distortional buckling should be considered whether or not the sheathing is attached to the compression flange. In 2015, the maximum discrete bracing spacing of 8 ft (2.44 m) on center is required based on design experience and common practice for flexural members such as curtain wall studs.

The Standard stipulates that when sheathing braced design is used, the wall stud shall be evaluated without the sheathing bracing for the dead loads and loads that may occur during construction, or in the event that the sheathing has been removed or has accidentally become ineffective. In 2014, the LRFD load combination for the United States and Mexico was taken from ASCE 7 (ASCE, 2006) for special event loading conditions.

Although the design approach for sheathing braced design is based upon engineering principles, the Standard limits the sheathing braced design to wall stud assemblies, assuming that identical sheathing is attached to both sides of the wall stud. This limit recognizes that identical sheathing will aid in minimizing the twisting of the section. If only single-sided sheathing is used, additional twisting of the section will occur, thus placing a greater demand on the sheathing; therefore, the stud must be designed and braced as an all steel assembly.

The provision that wall studs with sheathing attached to both sides that is not identical shall be permitted to be designed based on the assumption that the weaker of the two sheathings is attached to both sides is based on engineering judgment. Determination of which of the two sheathings is weaker shall consider the sheathing strength, sheathing stiffness and sheathing-to-wall stud connection capacity, as applicable.

B1.2.3 In-Line Framing

In-line framing is the preferred and most commonly used framing method. The advantage of in-line framing is that it provides a direct load path for transfer of forces from joists to studs. The Standard stipulates maximum framing alignment to minimize secondary moments on the framing members. Weak axis bending strength of track is minimal, and therefore the track cannot function as a load transfer member. In the absence of in-line framing, a load distribution member, such as a structural track, may be required for this force transfer.

Industry practice has accepted in-line framing to mean that the joist, rafter, truss and structural wall stud framing would be aligned so that the center line (mid-width) is within
¾ inch (19 mm) of the center line (mid-width) of the load-bearing members beneath. However, the ¾ inch allowable offset creates the possibility for a misalignment in the load path from an upper story load bearing stud wall, through a joist with a bearing stiffener, and onto a load-bearing stud or foundation wall below. In 2003, a total of 110 end- and interior-two-flange loading tests of various floor joist assemblies were carried out at the University of Waterloo (Fox, 2003) to determine the effect that an offset loading has on the strength of typical floors. It was concluded that an additional limit should be placed on the bearing stiffener offset to the load-bearing members above or beneath for cases where the bearing stiffener is attached to the back of the joist as depicted in Figure B1.2.3-1.

As an alternative to in-line framing, the Standard permits the use of a structural load distribution member that is specified in accordance with an approved design or approved design standard. As an aid to designers, strength and stiffness have been determined experimentally for various load-bearing top track assemblies (NAHB-RC, 2003; Dawe, 2005), including standard steel track, deep-leg steel track, and steel track with a 2x wood top plate. Design guidance for some of the typical top track load distribution members is available from the Cold-Formed Steel Engineers Institute (CFSEI, 2010a).

**B1.2.5.2 Principles of Mechanics**

The Standard does not aim to limit cold-formed steel light-framed shear walls, strap braced walls and diaphragms to the configurations included in the Standard. As such, the development of design values for other systems or configurations is permitted in accordance with rational engineering procedures and principles of mechanics. Design values based on calculations must, however, recognize the fundamental differences between the expected performance of structures under wind and seismic loads, and the performance of an individual lateral element. It must also be recognized that the tabulated design values in the Standard are based on test data for individual lateral elements. Recognition of these differences requires, where appropriate, that calculated values be scaled per existing design data. For wind design, there is no modification in design loads per the lateral resisting system used.

**B1.3 Built-Up Sections**

In 2007, a prescriptive end connection requirement for built-up compression members was added in Section D1.2 (2) of AISI S100 (AISI, 2007a) to preclude any shear slip in a built-up cold-formed steel section. This requirement was adopted from the AISC E6.2 (AISC, 2005a) and CAN/CSA S16.1 (CSA, 1994) structural steel specifications.

In order to determine the applicability of this prescriptive end connection requirement for double back-to-back cold-formed steel studs, a series of tests were conducted at the University of Missouri-Rolla (UMR). This research by Stone and LaBoube (2005) demonstrated that when a built-up stud is seated in a track section and bears on a firm surface, end slip is precluded; and thus the need for the additional fasteners is not required. The UMR research consisted of 32 tests of two C-shaped sections with edge stiffened flanges. The built-up sections tested were 82.6 inches (2.1 m) long, between 3-5/8 inches (92 mm) and 6 inches (152 mm) in depth, and between 33 mils (0.84 mm) and 54 mils (1.37 mm) thick. The studs were attached back-to-back with two rows of screws through the web starting 2 inches (50 mm) from each end and spaced at 12 inches (305 mm), 24 inches (610 mm) or 36 inches (914 mm) on-center. Each end of the built-up stud section was screwed to a standard track section 12 inches long which in turn was bearing on a 6\"x 8\"x ½\" (152mm x 203 mm x 12.7 mm) steel bearing plate. In order to simulate a pin connection representing an effective length factor of
unity, the steel bearing plate at each end was supported on a round bar.

In order to justify not specifying the end connection requirement of Section D1.2(b) of AISI S100, the designer must meet the bearing condition of support on steel or concrete to ensure relative slip of the two sections is prevented. This requires that the track must be supported over the entire area of the built-up member by steel or concrete components and that bearing stresses on the steel or concrete are within allowable limits.

**B1.5 Connection Design**

Self-drilling screws are the primary fastener type used in cold-formed steel construction, although the Standard does not preclude the use of other fastener types.

**B1.5.1 Screw Connections**

**B1.5.1.1 Steel-to-Steel Screws**

Screws are the primary fastener type used in cold-formed steel framed construction, although the Standard does not preclude the use of other fastener types. ASTM C1513 (ASTM, 2013) covers screws for the connection of cold-formed steel members manufactured in accordance with ASTM Specifications C645 and C955. This specification also covers test methods for determining performance requirements and physical properties. However, the tensile or shear strength must be determined by test in accordance with AISI S904 (AISI, 2013). General guidance on the selection of screws is given by the Cold-Formed Steel Engineers Institute document *Screw Fastener Selection for Cold-Formed Steel Frame Construction* (CFSEI, 2011).

Proper selection and installation of screws is necessary to ensure the design performance. Screws are specified using a nominal size designator, not by diameter. Table C-B1.5.1.1-1 defines suggested nominal screw diameters. The installation requirements stated in this Standard are based on industry practice. Selection of a minimum screw size is based on the total sheet thickness of the connection. Where recommendations are not available, Table C-B1.5.1.1-2 provides suggested screw size for steel-to-steel connections as a function of point style, per ASTM C1513, and total combined thickness of all connected steel members.

<table>
<thead>
<tr>
<th>Screw Nominal Size</th>
<th>Nominal Screw Diameter, d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(inches)</td>
</tr>
<tr>
<td>No. 6</td>
<td>0.138</td>
</tr>
<tr>
<td>No. 8</td>
<td>0.164</td>
</tr>
<tr>
<td>No. 10</td>
<td>0.190</td>
</tr>
<tr>
<td>No. 12</td>
<td>0.216</td>
</tr>
<tr>
<td>1/4”</td>
<td>0.250</td>
</tr>
</tbody>
</table>

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Table C-B1.5.1.1-2

Suggested Screw Sizes For Steel-to-Steel Connections

<table>
<thead>
<tr>
<th>Screw Size</th>
<th>Point Style</th>
<th>Total Thickness of Steel ¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(inches)</td>
</tr>
<tr>
<td>¼”</td>
<td>1</td>
<td>0.024 - 0.095</td>
</tr>
<tr>
<td>No. 6</td>
<td>2</td>
<td>0.036 - 0.100</td>
</tr>
<tr>
<td>No. 8</td>
<td>2</td>
<td>0.036 - 0.100</td>
</tr>
<tr>
<td>No. 10</td>
<td>2</td>
<td>0.036 - 0.110</td>
</tr>
<tr>
<td>No. 12</td>
<td>2</td>
<td>0.050 - 0.140</td>
</tr>
<tr>
<td>No. 14</td>
<td>2</td>
<td>0.060 - 0.120</td>
</tr>
<tr>
<td>No. 18</td>
<td>2</td>
<td>0.060 - 0.120</td>
</tr>
<tr>
<td>No. 8</td>
<td>3</td>
<td>0.100 - 0.140</td>
</tr>
<tr>
<td>No. 10</td>
<td>3</td>
<td>0.110 - 0.175</td>
</tr>
<tr>
<td>No. 12</td>
<td>3</td>
<td>0.090 - 0.210</td>
</tr>
<tr>
<td>No. 14</td>
<td>3</td>
<td>0.110 - 0.250</td>
</tr>
<tr>
<td>No. 12</td>
<td>4</td>
<td>0.175 - 0.250</td>
</tr>
<tr>
<td>¼”</td>
<td>4</td>
<td>0.175 - 0.250</td>
</tr>
<tr>
<td>No. 12</td>
<td>4.5</td>
<td>0.145 - 0.312</td>
</tr>
<tr>
<td>No. 12</td>
<td>5</td>
<td>0.250 - 0.500</td>
</tr>
<tr>
<td>¼”</td>
<td>5</td>
<td>0.250 - 0.500</td>
</tr>
</tbody>
</table>

¹ Combined thickness of all connected steel members

B1.5.1.3 Spacing and Edge Distance

AISI S100 [CSA S136] (AISI, 2012a; CSA, 2012) stipulates that the center-to-center spacing of screws be at least 3 times the screw diameter. During installation, if this spacing is only 2 times the diameter, research at the University of Missouri-Rolla (Sokol et al., 1999) has shown that the structural performance of the connection is reduced. Guidelines for center-to-center spacing of less than 2 times the diameter are not stipulated because the screw head diameter precludes a smaller spacing. The University of Missouri-Rolla research serves as the basis for the requirements in the Standard.

B1.5.1.4 Gypsum Board

The Standard employs the use of the applicable building code as the guide for provisions that cover the installation and attachment of gypsum panels to cold-formed steel framing. The model building codes in the United States reference ASTM C1007 (ASTM, 2011d) as the appropriate standard for the gypsum board attachment to cold-formed steel structural members.

The Standard requires that screw fasteners for gypsum board to steel connections be in compliance with ASTM C954 (ASTM, 2011a), ASTM C1002 (ASTM, 2014a) or ASTM C1513 (ASTM, 2013), as applicable, with a bugle head style. ASTM C954 is for fastening to steel having a thickness from 0.033 inches (0.84 mm) to 0.112 inches (2.84 mm). ASTM C1002 is for fastening to steel with a thickness less than 0.033 inches (0.84 mm). ASTM C1513 is for fastening to steel with a thickness not greater than 0.118 inches (2.997 mm).
B1.5.2 Welded Connections

Additional guidance on welding of cold-formed steel members is provided in the Cold-Formed Steel Engineers Institute document *Welding Cold-Formed Steel* (CFSEI, 2010b).

B1.5.3 Bolts

The Standard permits the use of bolts. Bolted connections can be designed by AISI S100 [CSA S136] equations.

B1.5.4 Power-Actuated Fasteners

The Standard permits the use of power-actuated fasteners. Connections using power-actuated fasteners can be designed by AISI S100 [CSA S136] equations.

B1.5.5 Other Connectors

The Standard permits the use of proprietary fasteners such as pneumatically driven pins, rivets, adhesives, and clinches. Proprietary fasteners must be designed and installed in accordance with the manufacturers’ requirements. The safety factor to be used in design is to be determined by Chapter F of AISI S100 [CSA S136]. The Cold-Formed Steel Engineers Institute has published technical notes pertaining to power-actuated fasteners and pneumatically driven pins (CFSEI, 2012; CFSEI, 2009).

B2 Floor and Ceiling Framing

B2.5 Bearing Stiffeners

The Standard provides provisions for clip angle bearing stiffeners, based on research at the University of Waterloo (Fox, 2006).

B2.6 Bracing Design

The continuous bracing and flange bracing provisions of the Standard were deemed appropriate due to the availability of research and field experience with such assemblies. The requirements in Section B2.6 were adapted from AISI S100 [CSA S136] requirements for members where neither flange is attached to sheathing.

B3 Wall Framing

B3.2 Wall Stud Design

B3.2.1 Axial Load

Prior to 2004, the *North American Specification for the Design of Cold-Formed Steel Structural Members* contained requirements for sheathing braced design in its Section D4(b). In 2004, these provisions were removed. AISI S100 [CSA S136], (AISI, 2012a; CSA, 2012) now permits sheathing braced design in accordance with an appropriate theory, tests, or rational engineering analysis.

Sheathing braced design in the Standard is based on rational analysis assuming that the sheathing braces the stud at the location of each sheathing-to-stud fastener location. Axial load in the stud is limited, therefore, by the capacity of the sheathing or sheathing-to-wall stud connection. Using the bracing principles as defined by Winter (1960) and summarized
by Salmon and Johnson (1996), the equilibrium of an imperfect column braced at mid-height, as illustrated in Figure C-B3.2.1-1, is expressed as:

\[ P(\Delta + \Delta_0) = k\frac{\Delta L}{2} \]  

(C-B3.2.1-1)

where

\[ \Delta = \text{Sidesway deflection at brace location beyond initial imperfection, } \Delta_0 \]

\[ \Delta_0 = \text{Initial imperfection} \]

\[ L = \text{Total stud height} \]

\[ k = \text{Bracing stiffness} \]

Following Eq. C-B3.2.1-1 to solve for deflection, \( \Delta \):

\[ \Delta = \frac{PA_0}{kL/4 - P} \]

When \( P \) approaches \( kL/4 \), the lateral deflection approaches infinity. Therefore, \( P_{cr} = kL/4 \). The bracing stiffness corresponding to \( P_{cr} \) is called \( k_{ideal} \) and \( k_{ideal} = 4P_{cr}/L \). To provide sufficient bracing to a column subjected to load \( P \), \( k \) needs to be greater than \( k_{ideal} \). It is common to choose \( k = 2k_{ideal} = 2(4P/L) \), and the corresponding deflection is:

\[ \Delta = \frac{PA_0}{2(4P/L) - P} = \frac{PA_0}{4(4P/L)^2 - P} \]

For \( \Delta_0 = L/960 \), the bracing force is

\[ F_{br} = k\Delta = 2\frac{4P}{L}\Delta_0 = 0.8\%P \]

\[ F_{br} = k\Delta = 2\frac{4P}{L}\Delta_0 = 0.8\%P \]

This result is consistent with the requirement of 1\%P from AISI S100 Equation D3.3-1. In this Standard, a more conservative approach has been taken by considering a safety factor of 2, which results in \( F_{br} = 2\%P \). Since the tests indicated a failure of the sheathing, not the screw-to-stud attachment, the Standard does not directly stipulate a design requirement to check the screw-to-stud capacity or the screw capacity in shear.

The strength of gypsum sheathing attached with No. 8 and No. 6 screws is based on
tests by Miller (1989) and Lee (1995), respectively. Based on engineering judgment, a factor of safety of 2.0 was applied to the ultimate load per screw (Table C-B3.2-1) when determining the brace strength per screw for the gypsum wallboard. The ultimate loads are based on the averaging of test data provided in Miller (1989) and Lee (1995).

<table>
<thead>
<tr>
<th>Sheathing</th>
<th>Screw Size</th>
<th>Ultimate Load (per screw)</th>
<th>Brace Strength [Resistance] (per screw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 inch (12.7 mm)</td>
<td>No. 6</td>
<td>0.117 kips (0.516 kN)</td>
<td>0.058 kips (0.258 kN)</td>
</tr>
<tr>
<td>1/2 inch (12.7 mm)</td>
<td>No. 8</td>
<td>0.134 kips (0.596 kN)</td>
<td>0.067 kips (0.298 kN)</td>
</tr>
<tr>
<td>5/8 inch (15.9 mm)</td>
<td>No. 6</td>
<td>0.136 kips (0.605 kN)</td>
<td>0.068 kips (0.302 kN)</td>
</tr>
<tr>
<td>5/8 inch (15.9 mm)</td>
<td>No. 8</td>
<td>0.156 kips (0.694 kN)</td>
<td>0.078 kips (0.347 kN)</td>
</tr>
</tbody>
</table>

The maximum axial nominal load provided in Table B3.2-1 of the Standard was determined by first multiplying the brace strength [resistance] per screw given in Commentary Table C-B3.2-1 by 2 to recognize that sheathing must be attached to both stud flanges and then dividing by 0.02 (i.e., 2%Pt), thus solving for the nominal load P that is given in Table B3.2-1 of the Standard.

The unbraced length with respect to the minor axis and the unbraced length for torsion are taken as twice the distance between the sheathing connectors in the event that an occasional attachment is defective to a degree that it is completely inoperative.

If plywood sheathing is attached to both flanges of the wall stud by screws spaced no greater than 12 inches (305 mm) on center, both the plywood and the stud must be checked. The following outlines a possible design solution for plywood attached to a wall stud:

**Evaluation of the Plywood:**

Using NDS (AFPA, 1997) Section 11.3,

Nominal Design Value (Brace Strength), \( Z = D \ell_m F_{em}/R_d \)

\( D = 0.164" \) (4.17 mm) (No. 8 Screw)

\( \ell_m = \text{Sheathing thickness} = 0.5" \) (12.7 mm)

\( R_d = 2.2 \) for \( D \leq 0.17" \) (4.32 mm)

\( F_{em} = 1900 \text{ psi (13,100 kPa)} \) (lowest bearing strength value – the values are based on the specific gravity of the wood)

\( Z = 0.164 \times 0.5 \times 1900 / 2.2 = 70.82 \text{ lbs. (315 N)} \)

Brace Force, \( F_{br} = 0.02 \text{ P, where P is the axial load in the stud.} \)

\( P = 70.82/0.02 = 3,540 \text{ lbs (15,700 N)} = 3.5 \text{ kips (15.6 kN) per screw x 2 screws} = 7.0 \text{ kips (31.1 kN) per stud} \)

**Evaluation of the Steel Wall Stud:**

The screw capacity in the stud can be evaluated using Section E4.3 of AISI S100 [CSA S136],

where

\( P_{ns} = 4.2 (t^3 d)^{0.5} F_u \leq 2.7 t_d F_u \)

\( \Omega = 3.0 \)

If \( P_{ns}/\Omega < Z \), the brace force analysis to determine \( P \) should be based on the lower
The capacity per screw is computed by the following equation:

\[ P = \frac{(P_{\text{ns}}/\Omega < Z)}{0.02} \]

Because the Standard requires that sheathing must be attached to both flanges of the wall stud, the nominal axial load in the wall stud is twice the value of \( P \).

**B3.2.5 Web Crippling**

**B3.2.5.1 Stud-to-Track Connection for C-Section Studs**

When the track thickness is equal to or greater than the stud thickness, an increase in web crippling strength can be realized. This increased strength is attributed to the favorable synergistic effect of the stud-to-track assembly. The provisions are based on research conducted at the University of Waterloo (Fox and Schuster, 2000) and the University of Missouri-Rolla (Bolte, 2003).

Two proposed design equations were considered for adoption by Section B3.2.5.1 of the Standard for evaluating the design strength of the stud-to-track connection for curtain wall applications. The proposed UMR equation (Bolte, 2003) reflected the specific contribution of the screw as follows:

\[ P_{\text{nst}} = P_n + \alpha P_{\text{not}} \]  
(C-B3.2.5.1-1)

where

\[ \alpha = 0.756 \]

\[ P_n = \text{Web crippling capacity in accordance with Section C3.4.1 of AISI S100 [CSA S136] for end one-flange loading} \]

\[ P_{\text{nst}} = \text{Nominal strength [resistance] for the stud-to-track connection when subjected to transverse loads} \]

\[ P_{\text{not}} = \text{Screw pull-out capacity in accordance with Section E4.4.1 of AISI S100 [CSA S136]} \]

The proposed equation (C-B3.2.5.1-2) was based on a formulation proposed by Fox and Schuster (2000). The design formulation for the stud-to-track connection was based on a pure web crippling behavior consistent with Section C3.4 of AISI S100 [CSA S136]. To reflect the positive contribution of the screw attachment, Fox and Schuster (2000) proposed modified web crippling coefficients as follows:

\[ P_n = Ct^2F_y \sin \theta \left( 1 - C_R \sqrt{\frac{R}{t}} \right) \left( 1 + C_N \sqrt{\frac{N}{t}} \right) \left( 1 - C_h \sqrt{\frac{h}{t}} \right) \] 
(C-B3.2.5.1-2)

where

\[ P_n = \text{Nominal web crippling strength [resistance] per Section C3.4.1 of AISI S100 [CSA S136]} \] with the following coefficients:

\[ C = \text{Web crippling coefficient} = 5.6 \]
\[ C_R = \text{Inside bend radius coefficient} = 0.01 \]
\[ C_N = \text{Bearing length coefficient} = 0.30 \]
\[ C_h = \text{Web slenderness coefficient} = 0.14 \]
\[ R = \text{Stud inside bend radius} \]
\[ N = \text{Stud bearing length} \]
\[ h = \text{Depth of flat portion of stud web measured along plane of web} \]
\[ t = \text{Stud design thickness} \]

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θ = Angle between plane of web and plane of bearing surface, 45°<θ≤90°

Based on the additional tests performed at UMR and the University of Waterloo, the following coefficients are recommended:

- **C** = Web crippling coefficient = 3.7
- **C_R** = Web slenderness coefficient = 0.19
- **C_N** = Bearing length coefficient = 0.74
- **C_h** = Inside bend radius coefficient = 0.019

Although there are pros and cons to each design equation, statistically they yield similar results as shown in the following:

**Table B3.2.5.1-1**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Waterloo Model</th>
<th>UMR Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.001</td>
<td>1.000</td>
</tr>
<tr>
<td>Coeff. of Variation</td>
<td>0.101</td>
<td>0.078</td>
</tr>
<tr>
<td>Ω</td>
<td>1.74</td>
<td>1.71</td>
</tr>
<tr>
<td>φ (LRFD)</td>
<td>0.88</td>
<td>0.90</td>
</tr>
</tbody>
</table>

The safety factor and resistance factor are based on assuming a member failure mode, not a connection failure mode.

Although both the UMR and University of Waterloo design methods will yield similar design strengths, for simplicity of design it was decided to adopt the University of Waterloo design method for the Standard. For simplicity, since θ = 90° and therefore sinθ = 1, the sinθ term was eliminated from Equation B3.2.5.1-1.

When the track thickness is less than the stud thickness, the proposed provisions are based on the study by Fox and Schuster (2000).

The 0.5 applied to Pnst for locations adjacent to wall openings is based on a study by Daudet (2001).

Further research on these stud-to-track connections was carried out in 2008 at the University of Waterloo (Lewis, 2008), with the objective being to extend the design provisions in Section B3.2.5.1 of the Standard to cover jamb stud members. These jamb studs can be single C-shaped members or built-up sections made from multiple members. The scope of testing was limited to the following:

1. Single C-shaped stud members located at the end of the track with two orientations of the stud: with the stiffening lips adjacent to the track end, and with the stud web adjacent to the track end.
2. Two C-shaped studs connected back-to-back, positioned in the track away from the track end, and positioned at the end of the track.
3. Two C-shaped studs connected toe-to-toe, positioned in the track away from the track end, and positioned at the end of the track.

The research showed that the web crippling expression in the Standard can be applied to all other combinations of single C-shaped and built-up members simply by changing the global web crippling coefficient, C. It was determined that the strength of other jamb stud configurations were multiples of the C=3.7 for a single stud. For example, a single member at the end of a track is 0.5C = 1.85; toe-to-toe or back-to-back
members are $2C = 7.40$; toe-to-toe members at the track end are $1.5C = 5.55$; and single stud at the track end with the stiffening lips adjacent to the opening are $0.75C = 2.78$. These results can only be applied within the range of the test parameters. For the web crippling failure mode to occur, the screws connecting the stud-to-track need to be sized according to the stud thickness. Provisions have been added for minimum screw sizes for the various stud thicknesses.

These tests were limited to combinations of stud and track where the track was the same thickness as the stud. This avoided the possibility of a track punch-through failure for the single C-shaped studs and for the toe-to-toe built-up members, but not for the back-to-back members. Consequently, a new design limit state for the track punch-through failure mode is proposed for the back-to-back built-up jamb members.

In situations where the back-to-back jamb stud configurations do not have screws connecting both flanges to the track, the web crippling strength [resistance] of the studs must be calculated using the provisions of AISI S100 [CSA-S136]. Since the AISI S100 web crippling calculations for back-to-back built-up sections overestimate the nominal strength [resistance] of these jamb studs, the nominal strength [resistance] is calculated using twice the AISI S100 web crippling capacity for a single web member.

The safety factors and resistance factors were determined based on the test data. As a result, there are different factors for different jamb stud configurations.

### B3.2.5.2 Deflection Track Connection for C-Section Studs

The provisions contained in the Standard apply to a C-section wall stud installed in a single deflection track application and are based on research at the Milwaukee School of Engineering (Gerloff, 2004). Based on this research, the load capacity [resistance] can be established by the equations in the Standard. The key parameters, as given by the equations, are illustrated by Figure C-B3.2.5.2-1.

Because the deflection track detail does not provide torsional restraint for the wall stud, it is recommended that a line of bridging be installed near the end of the member.

For Figure C-B3.2.5.2-1, dimension “e” is selected for the sum of construction tolerances and the deflection of the floor above relative to the floor or foundation below. Dimension “D” is selected so that adequate stud to track engagement and web crippling
bearing length remain when the floor below deflects relative to the floor above.

The background research for this provision did not include studs at or near terminations in the top track. For this case, the strength and serviceability of the connection may be reduced.

### B3.3 Header Design

Box and back-to-back header beams have been commonly used in cold-formed steel framing. The geometry is fabricated using two C-shaped cold-formed steel members. Design practice for such header beams can be based on AISI S100 [CSA S136], (AISI, 2012a; CSA, 2012). Research has determined that the application of AISI S100 [CSA S136] design provisions is conservative when track members are included in the assembly. This led to the development of an improved design methodology.

L-header beam geometries are gaining popularity in cold-formed steel framing. The geometry is fabricated using one or two L-shaped cold-formed steel members connected to a top track section. This geometry is commonly referred to as a single or double L-header because one or two angle shapes are used to create the header.

The header design provisions in the Standard do not attempt to provide a complete methodology for the design of openings in buildings. For such, the designer must consider numerous loading and serviceability issues (including out-of-plane loads) and design a complete load path consisting of members and connections that may include cripple studs, jack studs, king studs, head tracks and sill tracks. A useful reference for designers on this subject is the AISI Cold-Formed Steel Framing Design Guide (AISI, 2007).

#### B3.3.1 Back-to-Back Headers

The design methodology is based on review and analysis of the data presented in the NAHB (2003a) report Cold-Formed Steel Back-To-Back Header Assembly Tests (1997) and the study of Stephens (2000, 2001). The test results were evaluated and compared with the strength equations contained in the 2001 edition of the AISI Specification.

Stephens and LaBoube (2000) concluded that web crippling or a combination of bending and web crippling is the primary factor in header beam design for the IOF (interior one-flange) loading condition. Neither pure shear nor combined bending and shear were failure modes in the test program. The research study showed that using AISI S100 [CSA S136] web crippling equations for shapes having single webs for the design of box or back-to-back header beams gave conservative results.

#### B3.3.2 Box Headers

Based on studies conducted by Stephens (2001), a modification factor was derived that enables the computation of the interior one-flange web crippling capacity of a box header assembly as defined by Figure C3.4.4-2 of the Standard. The increased web crippling capacity is attributed to the interaction of the track section and the C-shaped section; thus, it is imperative that the track section be attached with the flanges as shown in Figure C3.4.4-2. This interaction is quantified by the ratio of track thickness to C-shaped section thickness in Eq. B3.3.2.3.1. When computing the web crippling capacity for a header assembly, the nominal capacity computed using AISI S100 [CSA S136] is to be multiplied by 2 to reflect that there are two webs in the assembly. In addition to a modification to the pure web crippling strength, the Standard also contains an interaction equation for bending and web crippling of box header assemblies that differs from AISI S100 [CSA S136]. This interaction
equation is based on the research of Stephens (2001), which included test specimens having standard perforations. Thus, the provisions of AISI S100 [CSA S136] are appropriate for header design.

If the top track section of a box header assembly is attached with the flanges up, as would be the case where the header beam is located directly above the opening and beneath the cripple studs, the provisions of Section B3.3.2.3 would not apply. Web crippling capacity and the combination of bending and web crippling should be evaluated by using Sections C3.4 and C3.5 of AISI S100 [CSA S136], and the equations for shapes having single unreinforced webs should be used.

The procedure to calculate the vertical deflection of a box or back-to-back header may be accomplished by using a composite assembly calculation, which would include the two C-shaped sections and the top and bottom tracks. However, to achieve full composite action, using this type of calculation would require an extensive (cost-prohibitive) fastener requirement between the tracks and the C-shaped sections; and therefore, it is more common to use a conservative estimate of the vertical deflection based on the full moment of inertia of the two C-shaped sections alone.

See Section B3.3.1, Back-to-Back Header, for additional information, as applicable.

**B3.3.3 Double L-Headers**

The available test data (Elhajj and LaBoube, 2000; and LaBoube, 2004) indicated that the failure mode was flexure or combination of flexure and web crippling. Neither pure shear nor combined bending and shear were failure modes in the test program. The tested moment capacity, \( M_t \), was determined and compared with the computed moment capacity as defined by Section C3.1.1(a) of AISI S100 [CSA S136]. The nominal flexural strength [resistance] was computed using the following equation:

\[
M_n = S_{xc} F_y
\]

where

\( F_y = \) Measured yield stress
\( S_{xc} = \) Elastic section modulus of the effective section computed at \( f = F_y \).

The section modulus of the compression flange was used for all computations.

It should be noted that the flexural strength is based on the section modulus of the compression flange; i.e., yielding of the shorter, horizontal leg of the angle. The inelastic reserve capacity of the longer, vertical leg is recognized and yielding in the extreme tensile fiber is not considered a limit state.

It should also be noted that when the design provisions of the Standard were developed, the elastic section modulus of the effective section was computed assuming that when the free edge of the element was in tension, Equations B2.3-3, B2.3-4 and B2.3-5 of AISI S100 [CSA S136] would apply regardless of the magnitude of \( h_0/b_0 \). Therefore, these assumptions are appropriate when calculating the elastic section modulus of the effective section using the Standard.

For typical L-headers having a geometry as defined by the limitations of Section B3.3.3, the performance of full-scale double L-header beam tests (Elhajj and LaBoube, 2000; and LaBoube, 2004) has shown that the limit states of shear, web crippling, bending and shear, and bending and web crippling need not be considered when designing an L-header beam. This is because shear and web crippling failures were not indicated in any of the tests, and because a simplified conservative design approach is used. Web crippling is effectively prevented by the way L-headers are assembled. However, designers are cautioned that an
L-header could potentially fail in shear for the combination of a very short span and a very large loading. Currently there are no limitations prescribed on minimum lengths or other factors that would prohibit shear failure in such cases. However, as a suggested procedure, shear should probably be considered when the span-to-depth ratio is less than 3.

The procedure to calculate the vertical deflection of an L-header is undefined because the L-header is an indeterminate assembly consisting of two angles, cripple studs, and track sections interconnected by self-drilling screws. However, the test results indicate that the measured assembly deflections at an applied load that equaled the nominal load [specified load] was less than L/240. Further analytical work, based on test data, would be necessary in order to develop a calculation procedure to determine the deflection of L-header beams.

**B3.3.3.1.1 Gravity Loading**

The test results summarized by Elhajj and LaBoube (2000) and LaBoube (2004) are considered to be confirmatory tests that show AISI S100 [CSA S136] Section C3.1.1 provides an acceptable determination of the nominal flexural strength [resistance].

For the 10-inch (254-mm)-deep L-header beams having the span to vertical leg dimension, L/L_h, greater than 10, the tested header sections had tested moment capacities greater than the computed moment capacity defined by Eq. B3.3.3.1.1-1 in the Standard. However, for 10-inch (254-mm)-deep beams having L/L_h ratios less than 10, the tested moment capacity was on the average 10% less than the computed moment capacity (Elhajj and LaBoube, 2000). Thus, the application of Eq. B3.3.3.1.1-1 is questionable for full range of the 10-inch (254-mm) L-headers. A review of the data indicates that the application of Eq. B3.3.3.1.1-1 is valid for test specimens having a span to vertical leg dimension, L/L_h, of 10 or greater. For the specimens having L/L_h ratios less than 10, it is proposed that the results obtained by using Eq. B3.3.3.1.1-1 be multiplied by 0.9.

**B3.3.3.1.2 Uplift Loading**

A comparison of the tested to computed moment capacity ratios ranged from 0.141 to 0.309 with a mean of 0.215 (Elhajj and LaBoube, 2000). Further analysis of the tested to computed moment ratios indicated that the behavior was influenced by the ratio of L_h/t. Therefore, uplift reduction factors, R, in the Standard were developed as a function of the L_h/t ratio.

Based on the provisions of Chapter F of AISI S100 [CSA S136], the safety factor was computed to be 2.0.

**B3.3.4 Single L-Headers**

Prior to 2003, the Standard excluded single L-headers. The NAHB Research Center (2003a) study that was completed prior to 2003 tested both single and double L-header beams. The tests consisted of either a single-point load or a two-point load. All angles had a 1.5 inch (38.1 mm) top flange. The vertical leg dimensions were either 6, 8, or 10 inches (152, 203 or 254 mm). Thicknesses ranged from nominally 0.033 to 0.068 inches (0.84 to 1.73 mm). Test span lengths ranged from 36 to 192 inches (914 to 4880 mm).

An analysis of the data indicated that the behavior of the L-headers differed for single-versus double-angle geometries. Also, the single-point load produced test results that differed from the two-point load. Prior to 2003, there was insufficient data to develop design guidelines for single-angle L-headers. Thus, the data analysis did not consider data...
for the single-angle sections nor for the single-point loading.

In 2003, testing was completed at the NAHB Research Center (2003a) on single L-header beams. The tests were similar to the previously tested double L-header beam tests, but header sizes were limited to vertical leg dimensions of 6 and 8 inches (152 or 203 mm), thicknesses ranged from nominally 0.033 to 0.054 inches (0.84 to 1.37 mm), and spans were limited to 4 feet (1.219 m). From this testing, sufficient data was provided to develop design guidelines for single L-headers within the range of parameters tested.

LaBoube (2004), based on testing by the NAHB Research Center (2003a), demonstrated that the design methodology for double L-headers in the 2001 edition of the AISI Standard for Cold-Formed Steel Framing – Header Design was acceptable for evaluating the gravity moment capacity of single L-headers, within the limitations of the test program. Uplift tests on single L-headers were not performed as part of this test program; however, Section B3.3.4.1.2 has been reserved in the Standard for this eventuality. Further, using the provisions of Section F1 of AISI S100 [CSA S136], the same $\Omega$ and $\phi$ factors that were prescribed in the 2001 edition of the AISI Standard for Cold-Formed Steel Framing – Header Design for the design of double L-headers would apply to single L-headers. As with previously tested double L-headers, neither pure shear nor combined bending and shear were failure modes for the tested single L-headers. Also, web crippling and combined bending and web crippling would be precluded from occurring because of the requirement that concentrated load applications occur at cripple stud locations.

**B3.3.5 Inverted L-Header Assemblies**

In 2005, provisions for inverted L-headers, as shown in Figure C-B3.3.5-1, were added to the Standard, based on rational engineering judgment, as a means to provide improved capacity for double and single L-headers.
B3.4 Bracing

The requirement in the Standard that each brace be designed for 2% of the design compression load [force] in the member is based on a long-standing industry practice. See further discussion in Commentary Section B3.2.1.

Bracing requires periodic anchorage. Bracing forces are accumulative between anchorage points.

B3.4.1 Intermediate Brace Design

Brace forces are additive, thus the Standard requires consideration of combined brace forces that when designing braces for members that experience combined loading. Design guidance is provided in AISI D110 (AISI, 2007).

B3.5 Serviceability


B4 Roofing Framing

B4.5 Bracing Design

The continuous bracing and flange bracing provisions of the Standard were deemed appropriate due to the availability of research and field experience with such assemblies. The requirements in Section B4.5(b) were adapted from AISI S100 [CSA S136] requirements for members where neither flange is attached to sheathing.

B5 Lateral Force-Resisting Systems

The lateral design provisions of the Standard were initially based on the requirements in the International Building Code (ICC, 2003) and the NFPA 5000 Building Construction and Safety Code (NFPA, 2003). The provisions in those codes evolved since the early work of Tarpy (1976-80), APA-The Engineered Wood Association (1993), Serrette (1995a) and the shear wall provisions that were first introduced into the 1997 Uniform Building Code (ICBO, 1997). Research conducted by Serrette at Santa Clara University and Dolan at Virginia Polytechnic Institute and State University form the technical basis for the initial design values in the Standard. Specific references to this research are cited in this Commentary. In 2007, provisions and design values related to shear wall and strap braced wall design, which are to be used with the 2005 National Building Code of Canada [NBCC] (NRCC, 2005), were added to the Standard based largely on research carried out under the supervision of Rogers at McGill University between 2005 and 2007. Specific references to this research are cited in the Commentary on ASI S400. At this time, the Standard does not address the Canadian design of diaphragms. Studies are ongoing, and it is expected that the Canadian design of these elements will be addressed in future editions of the Standard.

B5.2 Shear Wall Design

Shear walls are to be designed as either Type I shear walls or Type II shear walls.
B5.2.1 General

Type I shear walls are fully sheathed with steel sheet sheathing, wood structural panels, gypsum board panels, or fiberboard panels with hold-downs at each end. Type I shear walls sheathed with steel sheet sheathing or wood structural panels are permitted to have openings where details are provided to account for force transfer around openings. Figures C-B5.2.1-1(a) and C-B5.2.1-1(b) show typical Type I shear walls, with and without detailing for force transfer around window openings, and with hold-down anchors at the ends of each wall segment. Where wall assemblies are engineered for force transfer around openings and engineering analysis shows that uplift restraint at openings is not required, the assembly may be treated as a Type I shear wall and hold-downs are required at the ends of the assembly only, as illustrated in Figure C-B5.2.1-1(b).

Type II shear walls are sheathed with steel sheet sheathing or wood structural panels with a Type II shear wall segment at each end. Openings are permitted to occur beyond the ends of the Type II shear wall; however, the width of such openings shall not be included in the length of the Type II shear wall. Figure C-B5.2.1-2 shows a typical Type II shear wall.

Figure C-B5.2.1-1(a) Type I Shear Walls Without Detailing for Force Transfer Around Openings

Figure C-B5.2.1-1(b) Type I Shear Wall With Detailing for Force Transfer Around Openings
B5.2.2 Nominal Strength [Resistance]

Since the tabulated values in the Standard are based on test data, it was deemed necessary to provide the user with the limiting values of the tested systems. The intent is not to prevent an engineer from using judgment, the principles of mechanics and supplemental data to develop alternate shear values from those shown in the Standard, as discussed in Section B1.2.5.2 above.

For both wood structural panels and steel sheet sheathing, aspect ratios up to 4:1 are permitted with reductions in nominal strength. The reduced strength values are conservative based on 4:1 aspect ratio tests conducted by Serrette (1997).

A shear wall assembly using an approved adhesive to attach shear wall sheathing to the framing is not yet recognized by this Standard or by ASCE 7. Sufficient test data to justify acceptance of shear walls that use adhesive alone or in combination with fasteners to attach sheathing to the framing members was not available at the time this Standard was written. The limited existing test data indicates that shear walls using adhesives for sheathing attachment will generally not perform the same as shear walls with only fasteners attaching the sheathing to the framing.

Overdriving of the sheathing screws will result in lower strength, stiffness and ductility of a shear wall compared with the values obtained from testing (Rokas, 2006); hence, sheathing screws should be firmly driven into framing members but not overdriven into sheathing.

B5.2.2.1 Type I Shear Walls

In the United States and Mexico: The initial requirements for Type I shear walls in the Standard were based on studies by Serrette (1996, 1997 and 2002). This series of investigations included reverse cyclic and monotonic loading and led to the development of the design values and details for plywood, oriented strand board (OSB), and gypsum wall-board (GWB) shear wall assemblies that are included in the Standard.

In the United States and Mexico: In 2006, requirements were established for Type I shear walls with fiberboard panel sheathing based on studies by the NAHB Research Center (NAHB, 2005) and by the American Fiberboard Association (PFS, 1996 and NAHB, 2006). The nominal strength values for shear walls faced with fiberboard in Table B5.2.2.3-4 were based on monotonic tests of fiberboard sheathed, cold-formed steel framed shear walls and were compared to the tests that are the basis of the building code.
tabulated capacities for fiberboard sheathed, wood-framed shear walls. For the 2-inch (50.8 mm) and 3-inch (76.2-mm) edge screw spacing, the nominal strength values in Table B5.2.2.3-4 were based on the average peak load from tests of two 8-foot (2.438 m)-wide by 8-foot (2.428 m)-tall wall specimens. These nominal strength values were found to be within 90 percent of the nominal strength values for similarly sheathed wood-framed walls. The ratio of steel-to-wood nominal strength values increased as the edge (perimeter) fastener spacing increased and, therefore, extrapolating the 2/6 (92% ratio) and 3/6 (96% ratio) design values to 4/6 using a ratio of 90% was conservative. For the 4-inch (101.6 mm) edge screw spacing, the nominal strength values were calculated as 90 percent of the nominal strength value for a similarly sheathed wood-framed wall.

In the United States and Mexico: In 2011, the maximum aspect ratio of shear wall covered with 0.027” steel sheet sheathing on single side of the shear wall was established based on the experiments performed at the University of North Texas (Yu, 2007). In addition, the nominal strength values for 0.030” and 0.033” steel sheet sheathing on one side were added. The addition was also based on testing at the University of North Texas (Yu, 2007; Yu et al., 2009). Designation thicknesses of stud, track and blocking, and required sheathing screw size were added to the tables as well.

In the United States and Mexico: The Effective Strip Method for determining the nominal shear strength [resistance] for Type I shear walls with steel sheet sheathing is based on research by Yanagi and Yu (2014). The method assumes a sheathing strip carries the lateral load via a tension field action as illustrated in Figure C-B5.2.2.1-1. The shear strength of the shear wall is controlled by the tensile strength of the effective sheathing strip, which is determined as the lesser of the fasteners’ tensile strength and the yield strength of the effective sheathing strip. The statistical analysis in Yanagi and Yu (2014) yielded an LRFD resistance factor of 0.79 for the Effective Strip Method. In order to keep consistency in resistance factors (0.65 for LRFD) specified in Standard Section B5.2.3, the original design equation in Yanagi and Yu (2014) was adjusted accordingly.
In the United States and Mexico: The nominal strengths [resistances] were based on tests with studs with 1.5-inch (38 mm) x 4-inch (100 mm) punchouts at a center-to-center spacing of 24 inches (600 mm), anchor bolts with standard cut washers, and hold-down anchors on each end of the wall. As a result, the Standard permits the use of studs with standard punchouts and anchor bolts with standard cut washers, and requires hold-down anchors even though calculations may demonstrate that hold-down anchors are not necessary.

In the United States and Mexico: Factors were included, based on load duration factors given in the 2005 NDS (AFPA, 2005a) as shown in Table C-B5.2.2-1, to account for the influence of the duration of the applied load on wood strength to allow the tabulated values to be used for other in-plane lateral loads. Since the shear wall tests used as the basis of the Standard were carried out over a short time span, the tabulated values are for short-term duration loads (i.e., wind or seismic). However, the tabulated values for diaphragms were calculated using a load duration factor of 1.33, rather than the factor of 1.6 given in the 2005 NDS.

Table C-B5.2.2-1
United States and Mexico
AFPA NDS Load Duration Factors

<table>
<thead>
<tr>
<th>Load Duration</th>
<th>Factor</th>
<th>Typical Design Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent</td>
<td>0.9</td>
<td>Dead Load</td>
</tr>
<tr>
<td>Ten years</td>
<td>1.0</td>
<td>Occupancy Live Load</td>
</tr>
<tr>
<td>Two months</td>
<td>1.15</td>
<td>Snow Load</td>
</tr>
<tr>
<td>Seven days</td>
<td>1.25</td>
<td>Construction Load</td>
</tr>
<tr>
<td>Ten minutes</td>
<td>1.6</td>
<td>Wind/Earthquake Load</td>
</tr>
</tbody>
</table>

Figure C-B5.2.2.1-1 Effective Strip Method Model for Steel Sheet Sheathing
In Canada: Nominal resistance values for steel sheet sheathed and wood structural panel sheathed shear walls in AISI S240 match the values in AISI S400. Refer to the Commentary on AISI S400 for information on the derivation of these values. Nominal resistance values for gypsum and fiberboard sheathed shear walls in AISI S240 were set at 80% of the values found in Tables B5.2.2.3-3 and B5.2.2.3-4 for the United States. This reduction in resistance level is similar to what is found for the wood sheathed walls of similar construction, i.e. Table B5.2.2.3-2.

B5.2.2.2 Type II Shear Walls

The requirements for Type II shear walls, also known as perforated shear walls, in Section B5 were based on provisions in NEHRP (2000) for wood systems. In this method, the shear capacity ratio, F, or the ratio of the strength of a shear wall segment with openings to the strength of a fully sheathed wall segment without openings, is determined as follows:

\[
F = \frac{r}{3 - 2r}
\]

where

\[
r = \frac{1}{1 + \frac{A_0}{h \sum L_i}}
\]

- \(A_0\) = Total area of openings
- \(h\) = Height of wall
- \(\sum L_i\) = Sum of the length of full-height sheathing

Research by Dolan (1999, 2000a, 2000b) demonstrated that this design procedure is as valid for steel-framed systems as for all wood systems, and the IBC (ICC, 2003) and NFPA 5000 (NFPA, 2003) building codes both permit the use of Type II shear walls for steel systems. Test results revealed the conservative nature of predictions of capacity at all levels of monotonic and cyclic loading. The Standard does not provide a method or adjustment factor for estimating the lateral displacement of Type II shear walls. As such, the user should be cautious if a Type II shear wall is used in a deflection-sensitive design.

Table B5.2.2.2-1 in the Standard, which establishes an adjustment factor for the shear resistance, is based on the methodology described in this section and exists in essentially the same form in both the wood and steel chapters of the IBC (ICC, 2003) building code. There is also a similar table in AISI S230 (AISI, 2012h); however, AISI S230 establishes an adjustment factor for the shear wall length rather than the shear wall resistance.

Although the Dolan work was based on wood structural panel sheathing, the Committee felt it was appropriate to extend this methodology to shear walls with steel sheet sheathing due to the similar performance of wood structural panel sheathing and steel sheet sheathing in monotonic and cyclic tests (Serrette, 1997) of Type I shear walls.

In accordance with Section B5.2.2.2 in the Standard, it is required to check the height/length ratio of each Type II shear wall segment and reduce the strength of each segment that has an aspect ratio greater than 2:1, but less than or equal to 4:1 by the factor of \(2w/h\). This aspect ratio reduction factor is cumulative with the shear resistance adjustment factor, \(C_a\).
B5.2.3 Available Strength [Factored Resistance]

In the United States and Mexico: With the adoption of AISI S400, North American Standard for Seismic Design of Cold-Formed Steel Structural Systems, the seismic requirements, including the resistance factors, $\phi$, and safety factors, $\Omega$, were eliminated from AISI S240. Seismic design using the provisions of AISI S240 are only permitted in Seismic Design Category A, or in Seismic Design Categories B or C if the Response Modification Factor, $R$, in accordance with ANSI/ASCE 7-10 Table 12.2-1, is equal to 3. For these conditions, where special seismic detailing is not required, the lower resistance factor, $\phi$, and higher safety factor, $\Omega$, typically required for seismic design, are not warranted.

In Canada: The resistance factor ($\phi$) in AISI S240 matches the value in AISI S400. Refer to the Commentary on AISI S400 for information on the derivation of this value.

B5.2.5 Design Deflection

The deflection provisions are based on work performed by Serrette and Chau (2003). Equation C-B5.2.5-1 may be used to estimate the drift deflection of cold-formed steel light-framed shear walls recognized in the building codes. The equation should not be used beyond the nominal strength values given in the Standard. The method is based on a simple model for the behavior of shear walls and incorporates empirical factors to account for inelastic behavior and effective shear in the sheathing material. Specifically, the model assumes that the lateral deflection (drift) of a wall results from four basic contributions: linear elastic cantilever bending (boundary member contribution), linear elastic sheathing shear, a contribution for overall nonlinear effects, and a lateral contribution from anchorage/hold-down deformation. These four contributions are additive.

\[ \delta = \frac{2vh^3}{3E_sA_c b} + \frac{\omega_1 \omega_2}{\rho G_t \text{sheathing}} \frac{vh}{\omega_3 \omega_4} \left( \frac{v}{\beta} \right)^2 + \frac{h}{b} \delta_v \]  
\[ \text{Linear elastic cantilever bending: } \frac{2vh^3}{3E_sA_c b} \]  
\[ \text{Linear elastic sheathing shear: } \frac{\omega_1 \omega_2 vh}{\rho G_t \text{sheathing}} \]

Figure C-B5.2.5-1  Lateral Contribution From Anchorage/Hold-Down Deformation
Overall nonlinear effects: \( \omega_1^{5/4} \omega_2 \omega_3 \omega_4 \left( \frac{V}{\beta} \right)^2 \) (C-B5.2.5-4)

Lateral contribution from anchorage/hold-down deformation: \( \frac{h}{b} \delta_v \) (C-B5.2.5-5)

The lateral contribution from anchorage/hold-down deformation is dependent on the aspect ratio of the wall, as illustrated in Figure C-B5.2.5-1. The empirical factors used in the equation are based on regression and interpolation analyses of the reversed cyclic test data used in development of the cold-formed steel shear wall design values. The \( \rho \) term in the linear elastic sheathing shear expression attempts to account for observed differences in the response of walls with similar framing, fasteners and fastener schedules, but different sheathing material. Low values of \( \rho \) for steel sheet sheathing are a result of shear buckling in the sheath. The equations were based on Type I shear walls without openings, and the user should use caution if applying them to Type I shear walls with openings or to Type II shear walls. The shear wall deflection equations do not account for additional deflections that may result for other components in a structure (for example, wood sills and raised floors).

For wood structural panels, the shear modulus, G, is not a readily available value, except for Structural I plywood panels in the IBC (ICC, 2003) and UBC (ICBO, 1997) codes. However, the shear modulus may be approximated from the through thickness shear rigidity (\( G_{vt_v} \)), the nominal panel thickness (\( t \)) and through thickness panel grade and construction adjustment factor (\( C_G \)) provided in the AFPA Manual (AFPA, 2001). For example, G for 7/16-in. 24/16 OSB rated sheathing can be approximated as follows:

\( G_{vt_v} \) (24/16 span rating) = 25,000 lb/inch (strength axis parallel to framing)
\( t = 0.437 \) inch (as an approximation for \( t_v \))
\( C_G = 3.1 \)
\( G \) (approximate) = 3.1 \times 25,000 / 0.437 = 177,300 psi
Thus, \( C_G G_{vt_v} = 77,500 \) lb/inch and \( G_t = 77,500 \) lb/inch

A comparison of the \( C_G G_{vt_v} \) and \( G_t \) values suggests that using the nominal panel thickness as an approximation to \( t_v \) is reasonable given that the deflection equation provides an estimate of drift.

Currently, the shear wall deflection equations do not include provisions for gypsum board or fiberboard shear walls. However, the reader is reminded that given the low seismic response modification coefficient, \( R \), assigned by the building codes to gypsum board shear walls, it is expected that these systems will perform in the elastic range of behavior and deflections will be less likely to control the design.

In 2012, coefficients \( \beta \) and \( \rho \) in deflection Equation B5.2.5-1 were revised for Canadian Soft Plywood (CSP), and steel sheet sheathing, based on research results compiled by Cobeen (2010). CSP was differentiated from other plywoods based on the performance of that material. It should be noted that Canadian Douglas Fir Plywood (DFP) was found to behave similarly to plywood in common use in the United States.

**B5.3 Strap Braced Wall Design**

For strap braced walls, it is acceptable to compute the deflection using standard engineering analysis. Deflection calculations should consider all elements that contribute to the horizontal top of wall displacement, including axial deformation of the studs, elongation of the straps, and a lateral contribution from anchorage/hold-down deformation, as well as additional deflections that may result for other components in a structure (for example, wood
sills and raised floors). Because loose straps permit lateral displacement without resistance, the Standard requires that straps be installed taut.

**B5.4 Diaphragm Design**

The Standard does not currently address the design of diaphragms in Canada; however, pending the completion of research that is currently underway, it is expected that the design of diaphragms in Canada will be addressed in a future edition.

**B5.4.1 General**

The Standard permits the use of steel sheet sheathing, concrete or wood structural panels or other approved materials to serve as the diaphragm sheathing.

**B5.4.2 Nominal Strength**

The nominal strength of diaphragms is to be based upon principles of mechanics, per Section B1.2.5.1. Alternatively, for diaphragms sheathed with wood structural panels, the nominal strength may be determined by Section B5.4.2. The design values for diaphragms with wood structural panel sheathing in Table B5.4.2-1 were based on work by Lum (LGSEA, 1998). Lum developed ASD design tables using an analytical method outlined by Tissell (APA, 1993; APA 2000) for wood framing and the provisions of the 1991 NDS (AFPA, 1991). Because steel is not affected by splitting or tearing when fasteners are closely spaced, no reduction in the calculated strength was taken for closely spaced fasteners. In addition, although steel with designation thicknesses greater than 33 mil resulted in higher strength values, no increase in strength was included for these greater thicknesses.

It should be noted that flat strap used as blocking to transfer shear forces between sheathing panels is permitted, but is not required to be attached to framing members.

It should be noted that the diaphragm design values by Lum were based on the nominal strength of a No. 8 screw attaching wood structural panels to 33-mil cold-formed steel framing members. The 1991 NDS calculation methodology, which was used by Lum, yielded a nominal strength of 372 lbs and a safety factor of 3.3. However, the NDS methodology was revised in 2001, and the revision greatly reduced the calculated strength of screw connections. Until Lum’s work is updated, justification for maintaining the current diaphragm design values in the Standard are based, in part, on tests performed by APA (APA, 2005). Test results for single lap shear tests for a No. 8 screw attaching ½ in. plywood to 68-mil steel sheet sheathing indicated that the nominal strength [resistance] of the connection was governed by the strength of the screw in the steel sheet sheathing; i.e., the wood structural panels did not govern the capacity. Therefore, for thinner steel sheet sheathing, the limit state would likely be the tilting and bearing failure mode. For a No. 8 screw installed in 33-mil steel sheet sheathing, computations of connection capacity in accordance with AISI S100 [CSA S136] would yield a nominal strength of 492 lbs and a safety factor of 3.0. Additionally, connection tests for plywood attached to 33-mil cold-formed steel framing members were performed by Serrette (1995b) and produced an average ultimate connection capacity of 1177 lbs, and Serrette suggested the use of a safety factor of 6, as given by APA E380D. A review of the allowable strengths, as summarized in Table C-B5.4.2-1, indicates that although Lum’s design values are based on an earlier edition of the NDS, the value is conservative when compared to both AISI’s and Serrette’s results.
Table C-B5.4.2-1
No. 8 Screw Shear Strength (lbs) for 33-mil Cold-Formed Steel Member

<table>
<thead>
<tr>
<th></th>
<th>Lum</th>
<th>AISI 2001</th>
<th>Serrette</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal</td>
<td>Allowable</td>
<td>Nominal</td>
<td>Allowable</td>
</tr>
<tr>
<td>372</td>
<td>112</td>
<td>492</td>
<td>164</td>
</tr>
</tbody>
</table>

**B5.4.4 Design Deflection**

The methodology for determining the design deflection of diaphragms was based on a comparison of the equations used for estimating the deflection of wood frame shear walls and diaphragms, coupled with similarities in the performance of cold-formed steel and wood frame shear walls. Collectively, these comparisons suggested that the wood frame diaphragm equation could be adopted, with modifications to account for the difference in fastener performance, for application to cold-formed steel light-frame construction. The current equation for wood frame construction (ICC, 2003) is as follows:

\[
\Delta = \frac{5vL^3}{8EA} + \frac{vL}{4G} + 0.188Le_n + \frac{\sum (\Delta_cX)}{2b} 
\]

For SI:

\[
\Delta = \frac{0.052vL^3}{EA} + \frac{vL}{4G} + \frac{Le_n}{1627} + \frac{\sum (\Delta_cX)}{2b} 
\]

where
- \(A\) = Area of chord cross-section, in square inches (mm²)
- \(b\) = Diaphragm width, in feet (mm)
- \(E\) = Elastic modulus of chords, in pounds per square inch (N/mm²)
- \(e_n\) = Nail deformation, in inches (mm)
- \(G\) = Modulus of rigidity of wood structural panel, in pounds per square inch (N/mm²)
- \(L\) = Diaphragm length, in feet (mm)
- \(t\) = Effective thickness of wood structural panel for shear, in inches (mm)
- \(v\) = Maximum shear due to design loads in the direction under consideration, in pounds per linear foot (N/mm)
- \(\Delta\) = The calculated deflection, in inches (mm)
- \(\Sigma (\Delta_cX)\) = Sum of individual chord-splice values on both sides of the diaphragm, each multiplied by its distance from the nearest support

Equations C-B5.4.4-1 and C-B5.4.4-2 apply to uniformly nailed, blocked diaphragms with a maximum framing spacing of 24 inches (610 mm) on center. For unblocked diaphragms, the deflection must be multiplied by 2.50 (APA, 2001). If not uniformly nailed, the constant 0.188 (For SI: 1/1627) in the third term must be modified accordingly.

In 2012, coefficients \(\beta\) and \(\rho\) in deflection Equation B5.2.5-1 were revised based on research work by Cobeen (2010). Based on shear wall performance, similar revisions were made to the deflection Equation B5.4.4-1 for the diaphragm systems.

**B5.4.5 Beam Diaphragm Tests for Non-Steel Sheathed Assemblies**

Consistent with wood-framed construction, for the in-plane diaphragm, the nominal shear strength [resistance] is permitted to be determined by a beam test in accordance with ASTM E455 (2011e). The nominal shear strength is to be the average of a minimum of three tests in accordance with AISI S100 [CSA S136] Section F1.1(a).
The determination of the safety factor and resistance factor, when failure occurs in the cold-formed steel member or sheathing-to-steel fasteners, is based on the screw connection statistics from AISI S100 [CSA S136] Chapter F and is consistent with AISI S100 [CSA S136], Section D6.2.1.

The safety factor of 2.8 and resistance factor of 0.6 are used to be consistent with the wood sheathing failure as prescribed by the wood industry (AFPA, 2008).

The beam test provides diaphragm performance for an essentially rectangular building configuration. The aspect ratio of 4:1 reflects the limit for essentially rectangular buildings as prescribed by AISI S230.
C. INSTALLATION

C2 Material Condition

To ensure structural performance is in compliance with the engineered design, structural members, connectors, hold-downs and mechanical fasteners must not be damaged. Damage assessment is not within the purview of this Standard. The design professional should be consulted when damage alters the cross-section geometry of a structural member, or damages to connectors, hold-downs and mechanical fasteners beyond the specified tolerances.

C2.1 Web Holes

AISI S100 [CSA S136] stipulates design requirements for members with standard web holes. In the field, these “web holes” may also be referred to as “punchouts,” “utility holes,” “perforations” and “web penetrations.” In structural members, web holes are typically 1.5 in. (38 mm) wide × 4 in. (102 mm) long and are located on the center line of the web. The web holes are generally spaced 24 in. (610 mm) on center.

C2.2 Cutting and Patching

This Standard places restrictions on acceptable methods for cutting of framing members so that cut edges are not excessively rough or uneven and protective metallic coatings are not damaged in areas away from cut edges. It is noted that shearing includes a variety of mechanical methods including, but not limited to, the use of hydraulic shears and hole punches during manufacturing; and portable hydraulic shears, hand-held electric shears, aviation snips, and hole punches during fabrication and installation.

Coping, cutting or notching of flanges and edge stiffeners is not permitted for structural members without an approved design. For guidance on design for coped members in trusses, refer to Section E4.6.2.

C2.3 Splicing

Structural members may be spliced; however, splicing of studs and joists is not a common practice and is not recommended. If a structural member requires splicing, the splice connection must be installed in accordance with an approved design.

C3 Structural Framing

C3.1 Foundation

An uneven foundation may cause problems. The specified ¼ in. (6.4 mm) gap has been deemed acceptable industry practice.

C3.2 Ground Contact

To minimize the potential for corrosion, care must be taken to avoid direct contact between the cold-formed steel framing and the ground. In addition to direct contact, it is important to minimize the potential for corrosion resulting from ambient moisture. The applicable building code is cited as the authoritative document that will provide guidance concerning minimum separation distances from the ground to the framing member, installation requirements for moisture barriers, and the necessary ventilation of the space.
C3.3 Floors

To avoid premature failure at a support and to achieve in-line framing, full bearing of the joist on its supporting wall is necessary. The intent of specifying that the track and joist webs are not to be in direct contact with each other is to prevent floors from creating an unwanted noise (e.g. squeaks).

C3.4 Walls

C3.4.1 Straightness, Plumbness and Levelness

Wall studs must be installed plumb to avoid the potential for secondary bending moments in the member. In 2015, a reference to tolerances in ASTM C1007 (ASTM, 2011d) for plumbness and levelness was added.

C3.4.3 Stud-to-Track Connection

The stud must be nested and properly seated into the top and bottom track to provide for adequate transfer of forces and minimize axial deflections. Each flange of the stud should also be attached to the tracks to brace the top and bottom of the stud against weak axis and torsional displacements.

The maximum end gap specified by this Standard is based on traditional industry practice. The gap specified in Section C3.4.3(a) is only for axial load bearing walls, which is defined in Section 202 of the IBC (ICC, 2012) as any metal or wood stud wall that supports more than 100 pounds per linear foot (1459 N/m) of vertical load in addition to its own weight.

Axial loads in a wall stud in excess of the capacity of the screw connection between the stud and its seating tracks will be transferred between the stud and track in bearing. In this situation, if a stud is not properly seated, relative movement between the stud and the track may occur, which reduces or closes any gap between the end of the stud and the track.

To determine the influence of this relative movement between the stud and the track on the serviceability of sheathed wall assemblies, a testing program was conducted at the University of Missouri-Rolla (Findlay, 2005). The UMR test program only considered the stud and the track having the same thickness. For thinner stud and track materials (0.054 inches (1.37 mm) or less), testing showed that relative movement between the stud and the track was accommodated through a combination of track deformation and screw tilting. In these cases the connection remained intact and was capable of resisting uplift forces and preventing stud weak axis and torsional displacement. For thicker materials (greater than 0.054 inches), testing showed that the relative movement between the stud and the track could result in shear failure of the screws. In these cases, testing indicated a smaller end gap tolerance (e.g., 1/16 inch (1.59 mm)) would be desirable to limit relative movement and potential screw failure.

In addition to a smaller specified end gap to avoid potential screw failure in track thicker than 0.054 inches (1.37 mm), a smaller specified gap may also be desirable for multi-story structures where the accumulation of gap closures may become significant. Special considerations may also be desirable for heavily loaded cold-formed steel structures and conditions susceptible to deflections.

One method to help achieve adequate end bearing and minimize undesirable relative movement between the stud and the track is to specify a smaller 1/16 in. (1.59 mm) gap. This is a relatively simple criterion to verify. However, not exceeding the 1/16 in.
Another method to achieve adequate end bearing is to pre-compress the *stud* inside the *track*. This is often accomplished when panelizing the *stud* walls and pre-compressing the wall panel before connecting the *track* to the *stud*. Wall panelization and pre-compression, particularly for multi-story cold-formed steel construction, has become a common practice in several regions of North America. With pre-compression, it can be relatively assured that the *stud* will be seated in the *track*, regardless of the gap after pre-compression. At present, there are no specific guidelines for the amount of pre-compressive force required to assure proper seating. Industry practice has been to compress the wall panel until the *studs* visually seat inside the radius of the *track* and before the *studs* begin to buckle. Jacking force will vary depending upon the *stud* size and wall panel height, but is typically several hundred pounds minimum per *stud*. Guidelines for verification of proper pre-compression are nonexistent, but typically pre-compression will result in gaps of 1/16 in. (1.59 mm) or less for the majority of *stud*-to-*track* connections, with no gap exceeding 1/8 inch.

A third method to help ensure adequate end bearing is to oversize the *web* depth of the *track* to minimize any gap. *Track* oversized 1/16 to 1/8 in. (1.59 mm to 3.18 mm) will usually have a flat *web* between the *track* radii that is greater than the depth of the *stud*, enabling the *stud* to bear directly on the *web* instead of the *track* radii. This method will often be desirable when bearing walls are stick-framed instead of panelized and pre-compressed. One disadvantage is the oversized *track* may make a flat wall finish more difficult.

For all thickness of materials, testing has shown that the gap between the sheathing and the floor should be equal to or greater than the gap between the *stud* and the *track*.

### C3.5 Roofs and Ceilings

Proper installation and alignment of *roof joists* and *ceiling joists* is necessary to ensure the proper load transfer from the *rafter/ceiling joist connection* to the wall framing. To avoid premature failure at a support and to achieve in-line framing, full bearing of the *joist* on its supporting wall framing member or a minimum 1-1/2 inch (38 mm) end bearing is necessary.

### C3.6 Lateral Force-Resisting Systems

Proper installation, consistent with the construction of the tabulated systems that were tested, is deemed necessary for the performance of the system. Flat *strap* used as *blocking* to transfer shear forces between sheathing panels is permitted, but is not required to be attached to framing members. For *wood structural panel*, gypsum board and *fiberboard* sheathing, screws must be installed through the sheathing to the *blocking*. Sheathing *screws* should be driven to the proper depth appropriate for the head style used. *Bugle*, wafer and flat head screws should be driven flush with the surface of the sheathing; *pan head*, *round head*, and *hex-washer head* screws should be driven with the bottom of the head flush with the sheathing. See Commentary Section B5.2.2.1 for more discussion on overdriving sheathing screws.
C4 Connections

C4.1 Screw Connections

C4.1.2 Installation

Screw length must be adequate to ensure that screw fasteners extend through the steel connection a minimum of three (3) exposed threads, as illustrated in Figure C-C4.1.2-1.

![Figure C-C4.1.2-1 Screw Grip Range](image)

C4.1.3 Stripped Screws

It is unreasonable to expect that there will be no stripped screws in a connection. Research at the University of Missouri-Rolla (Sokol et al., 1999) has shown that the structural performance of a single-shear screw connection is not compromised if screws in the connection have been inadvertently stripped during installation. This research serves as the basis for the requirements of the Standard.

C4.2 Welded Connections

To maintain acceptable durability of a welded connection, the weld area must be treated with a corrosion-resistant coating, such as a zinc-rich paint.

C5 Miscellaneous

C5.1 Utilities

C5.1.1 Holes

The design should include references to pre-punch hole sizes or limitations to accommodate electrical, telecommunication, plumbing and mechanical systems. Field-cut holes are generally discouraged, but are not uncommon. Field-cut holes, if necessary, are required to comply with Section C2.1. There are several methods whereby holes can be cut in the field, such as a hole-punch, hole saws, and plasma cutters.

Holes that penetrate an assembly containing steel framing that has a fire resistance rating will need to be designed with through-penetration firestop systems. The acceptance of this fire resistance design is based on the applicable building code.
C5.1.2 Plumbing

Direct contact with copper piping should be avoided in order to prevent galvanic action from occurring. Methods for preventing the contact from occurring may be through the use of nonconductive and noncorrosive grommets at web penetrations or through the use of nonmetallic brackets (a.k.a. isolators) fastened to hold the dissimilar metal building products (e.g. piping) away from the steel framing. Plastic pipe does not require protection if it is in contact with the cold-formed steel framing member, but consideration should be made for the installation of nonmetallic brackets to hold the pipe away from the hole in the steel in order to prevent noise and prevent the steel from cutting into the pipe.

C5.1.3 Electrical

Nonmetallic sheathed wiring must be separated from the cold-formed steel framing member in order to comply with the National Electrical Code (NFPA, 2011). Contained within the National Electrical Code is a provision that requires nonmetallic sheathed cable to “be protected by bushings or grommets securely fastened in the opening prior to the installation of the cable.” Cable following the length of a framing member will need to be secured (e.g., supported) at set lengths; for this purpose, small holes in the web may be beneficial for the attachment of tie-downs (e.g. nylon cable ties, nylon zipper ties, etc.). When installing wiring or cables within a framing member (e.g., through or parallel to member), the intent of the National Electrical Code further requires that the wiring or cables be located 1-1/4 inches (32 mm) from the edge of the framing member. When 2-1/2-inch (64-mm)-wide wall studs are used, the restrictions concerning edge clearance apply.

C5.2 Insulation

The cavity insulation must be installed such that the width of the insulation extends from the face of the web of one framing member to the face of the web of the next framing member. In the case of cold-formed steel framing, designs should specify “full-width” insulation in order to differentiate the insulation that is normally supplied (nominal width).

To enhance the thermal performance of cold-formed steel framed construction, board insulation (such as continuous insulation or insulating sheathing) may be used in conjunction with cavity insulation. Guidance on the use of board and batt insulation is given in Thermal Design and Code Compliance for Cold-Formed Steel Walls (SFA, 2008). Designs should also take into consideration the effects of moisture when assessing the application of both cavity and continuous insulation, in this case dew point. The ASHRAE Handbook of Fundamentals contains information useful for determining dew point (ASHRAE, 2009).
D. QUALITY CONTROL AND QUALITY ASSURANCE

D1 General

D1.1 Scope and Limits of Applicability

Chapter D provides minimum requirements for quality control and quality assurance for material control and installation for cold-formed steel light-frame construction. Minimum observation and inspection tasks deemed necessary to ensure quality cold-formed steel light-frame construction are specified.

Chapter D does not apply to cold-formed steel nonstructural members. Chapter D does not apply to the manufacture of cold-formed steel structural members, connectors or hold-downs other than material control, nor to manufacture of mechanical fasteners or welding consumables. Chapter D does not address quality control or quality assurance for other materials and methods of construction.

In Chapter D, material control refers to the general oversight of the materials by the component manufacturer and installer and involves procedures for storage, release and movement of materials. Throughout the manufacturing and construction processes, including the associated inspections, materials are identified and protected from degradation. Additionally, nonconforming items are identified and segregated as needed.

The Chapter D requirements are patterned after similar requirements developed by the American Institute of Steel Construction for structural steel and the Steel Deck Institute for steel deck.

Chapter D defines a comprehensive system of quality control requirements on the part of the component manufacturer and installer and similar requirements for quality assurance on the part of the project representatives of the owner when such is deemed necessary to complement the contractor’s quality control function. These requirements exemplify recognized principles of developing involvement of all levels of management and the workforce in the quality control process as the most effective method of achieving quality in the constructed product. Chapter D supplements these quality control requirements with quality assurance responsibilities as are deemed suitable for a specific task.

AISI S202, Code of Standard Practice for Cold-Formed Steel Structural Framing (AISI, 2011), indicates that the component manufacturer or installer is to implement a quality control system as part of their normal operations. The registered design professional should evaluate what is already a part of the component manufacturer’s or installer’s quality control system in determining the quality assurance needs for each project. Where the component manufacturer’s or installer’s quality control system is considered adequate for the project, including compliance with any specific project needs, the “special inspection” or quality assurance plan may be modified to reflect this. Similarly, where additional needs are identified, supplementary requirements should be specified.

The terminology adopted for use in Chapter D is intended to provide a clear distinction of component manufacturer and installer requirements and the requirements of others. The definitions of quality control and quality assurance used here are consistent with usage in related industries. It is recognized that these definitions are not the only definitions in use.

For the purposes of this Standard, quality control includes those tasks performed by the component manufacturer and installer that have an effect on quality or are performed to measure or confirm quality. Quality assurance tasks performed by organizations other than
the component manufacturer and installer are intended to provide a level of assurance that the product meets the project requirements. The terms quality control and quality assurance are used throughout Chapter D to describe inspection tasks required to be performed by the component manufacturer and installer and representatives of the owner, respectively. The quality assurance tasks are inspections often performed when required by the applicable building code or authority having jurisdiction, and designated as “special inspections,” or as otherwise required by the project owner or registered design professional.

D1.2 Responsibilities

The requirements in Chapter D are considered adequate and effective for most cold-formed steel light-frame construction.

Where the applicable building code and authority having jurisdiction require the use of a quality assurance program, Chapter D outlines the minimum requirements deemed effective to provide satisfactory results in cold-formed steel light-frame construction. There may be cases where supplemental inspections are advisable. Additionally, where the contractor’s quality control program has demonstrated the capability to perform some tasks that this plan has assigned to quality assurance, modification of the plan could be considered.

D2 Quality Control Programs

Many quality requirements are common from project to project. Many of the processes used to produce cold-formed steel light-frame construction have an effect on quality and are fundamental and integral to the component manufacturer’s or installer’s success. Consistency in imposing quality requirements between projects facilitates more efficient procedures for both. The construction documents referred to in Chapter D are, of necessity, the versions of the plans, specifications, and approved shop drawings and approved installation erection drawings that have been released for construction, as defined in AISI S202. When responses to requests for information and change orders exist that modify the construction documents, these are also part of the construction documents. When a building information model is used on the project, it is also a part of the construction documents.

Elements of a quality control program can include a variety of documentation such as policies, internal qualification requirements, and methods of tracking production progress. Any procedure that is not apparent subsequent to the performance of the work should be considered important enough to be part of the written procedures. Any documents and procedures made available to the quality assurance inspector should be considered proprietary and not distributed inappropriately.

The inspection documentation should include the following information:

1. The product inspected
2. The process that was conducted
3. The name of the inspector and the time period within which the inspection was conducted
4. Non-conformances and corrections implemented

Records can include marks on pieces, notes on drawings, process paperwork, or electronic files. A record showing adherence to a sampling plan for pre-welding compliance during a given time period may be sufficient for pre-welding observation inspection.

The level of detail recorded should result in confidence that the product is in compliance with the requirements.
D3 Quality Control Documents

D3.1 Documents to be Submitted

The documents listed must be submitted so that the registered design professional can evaluate that the items prepared by the component manufacturer or installer meet the registered design professional’s design intent. This is usually done through the submittal of shop drawings and installation drawings. In many cases digital building models are produced in order to develop shop drawings and installation drawings. In lieu of submitting shop drawings and installation drawings, the digital building model can be submitted and reviewed by the registered design professional for compliance with the design intent. For additional information concerning this process, refer to the AISC Code of Standard Practice for Steel Buildings and Bridges Appendix A, Digital Building Product Models.

The exception in Section D3.1.1.3 limits the additional requirements in Sections D3.1.1.1 and D3.1.1.2 to lateral force-resisting systems with relatively high capacities.

D3.2 Available Documents

The documents listed must be made available for review by the registered design professional. In some instances, the registered design professional may require the submittal of additional documents. Certain items are of a nature that submittal of substantial volumes of documentation is not practical, and therefore it is acceptable to have these documents reviewed at the component manufacturer’s or installer’s facility by the registered design professional or quality assurance agency. Additional commentary on some of the documentation listed in this section is as follows:

(a) Documents related to connectors, hold-downs and mechanical fasteners are required only in cases where connectors, hold-downs and mechanical fasteners are being installed.

(b) Documents related to welding are required only in cases where welding of cold-formed steel structural members is being performed.

(c) Specific welders may not be known until installation begins; therefore, welding personnel performance qualification records may not be made available until immediately before installation begins.

(d) Because the selection and proper use of welding filler metals is critical to achieving the necessary levels of strength and quality, the availability for review of welding filler metal documentation and welding procedure specifications (WPSs) is required. This allows a thorough review on the part of the registered design professional, and allows the registered design professional to have outside consultants review these documents, if needed.

(e) The component manufacturer and installer maintain written records of welding personnel qualification testing. Such records should contain information regarding date of testing, process, welding procedure specifications, test plate, position, and the results of the testing. In order to verify the six-month limitation on welder qualification, the component manufacturer and installer should also maintain a record documenting the dates that each welder has used a particular welding process.
D5 Inspection Personnel

D5.1 Quality Control Inspector

The component manufacturer or installer determines the qualifications, training and experience required for personnel conducting the specified inspections. Qualifications should be based on the actual work to be performed and should be incorporated into the component manufacturer’s or installer’s quality control program. Inspection of welding should be performed by an individual who, by training and/or experience in metals fabrication, inspection and testing, is competent to perform inspection of the work. Recognized certification programs are a method of demonstrating some qualifications, but they are not the only method nor are they required by Chapter D for quality control inspectors.

D5.2 Quality Assurance Inspector

The quality assurance agency determines the qualifications, training and experience required for personnel conducting the specified quality assurance inspections. This may be based on the actual work to be performed on any particular project. Qualification for the quality assurance inspector may include experience, knowledge and physical requirements. These qualification requirements are documented in the quality assurance agency’s written practice. AWS B5.1 (AWS, 2003) is a resource for qualifications of a welding inspector.

D6 Inspection Tasks

D6.1 General

Chapter D defines two inspection levels for required inspection tasks and labels them as either “observe” or “perform.” This is in contrast to common building code terminology which uses or has used the terms “periodic” or “continuous.” However, this is consistent with the AISC and SDI standards that were used as a pattern for this Standard.

The tables in Sections D6.5 through D6.9 list the required inspection tasks for quality control and quality assurance. If inspections identify nonconforming material or workmanship, the need for additional inspections and rejection of material is to be assessed in accordance with Section D7.

The tables in Sections D6.5 through D6.9 also list the required documentation tasks for quality assurance. Documentation tasks for quality control are not required by Chapter D, but should be as defined by the applicable quality control program of the component manufacturer or installer.

D6.2 Quality Control Inspection Tasks

Quality control documentation is an internal record for the component manufacturer or installer to record that the work has been performed and that the work is in accordance with the shop drawings or construction documents, as applicable. Depending upon the component manufacturer’s or installer’s quality control program, the method of documentation may vary.

Model building codes, such as the International Building Code (ICC, 2015), often make specific statements about performing inspections to approved construction documents. AISI S202 requires the transfer of information from the contract documents into accurate and complete shop drawings and installation drawings. Therefore, relevant items in the plans and specifications that must be followed in component manufacturing and installation should be placed on the shop drawings and installation drawings, or in typical notes issued for the project. Because of
this provision, quality control inspection may be performed using shop drawings and installation drawings, not the original plans and specifications.

D6.3 Quality Assurance Inspection Tasks

Model building codes, such as the International Building Code (ICC, 2015), make specific statements about performing inspections to approved construction documents. Accordingly, the quality assurance inspector should perform inspections using the original plans and specifications. The quality assurance inspector may also use the shop drawings and installation drawings to assist in the inspection process.

D6.4 Coordinated Inspection

Coordination of inspection tasks may be needed for component manufacturers in remote locations or distant from the project itself, or for installers with projects in locations where inspection by a local firm or individual may not be feasible or where tasks are redundant. The approval of both the authority having jurisdiction and registered design professional is required for quality assurance to rely upon quality control, so there must be a level of assurance provided by the quality activities that are accepted.

D6.5 Material Verification

Compliance of cold-formed steel structural members typically includes verification of product identification in accordance with Section A5.5 and shape dimensions and sizes in accordance with an approved design or approved design standard. The manufacturer of cold-formed steel structural members is typically responsible for verification of material in accordance with Section A3, corrosion protection in accordance with Section A4, and base steel thickness in accordance with Section A5.1.

The installer should consider Section G1.1 of AISI S202 when establishing material control procedures for cold-formed steel structural members. Cold-formed steel structural members that lack product identification are typically tested to determine conformity.

D6.6 Inspection of Welding

Compliance of welds typically includes verification of weld size, length and location.

D6.7 Inspection of Mechanical Fastening

Compliance of mechanical fasteners typically includes verification of mechanical fastener type, diameter, length, quantity, spacing, edge distance and location.

D6.8 Inspection of Cold-Formed Steel Light-Frame Construction

Compliance of cold-formed steel light-frame construction typically includes verification of component assembly, structural member and connector sizes and locations; bracing, blocking and bearing stiffener sizes and locations; and bearing lengths.

D6.9 Additional Requirements for Lateral Force-Resisting Systems

Compliance of cold-formed steel lateral force-resisting system installation typically includes verification of shear walls; diagonal strap bracing and gusset plates; hold-downs and anchor bolts; collectors (drag struts); and diaphragms.

The exception in Section D6.9 limits the additional requirements to lateral force-resisting systems with relatively high capacities.
In Table D6.9-2, a welder identification system is a system maintained by the *component manufacturer or installer*, as applicable, by which a welder who has welded a joint or member can be identified.
E. TRUSSES

E1 General

E1.1 Scope and Limits of Applicability

Cold-formed steel trusses are planar structural components. Structural performance depends on the trusses being installed vertically, in-plane, and at specific spacing, and being properly fabricated and braced. The Standard describes the materials used in a cold-formed steel truss, as well as design, fabrication, and bracing procedures for truss members.

This Standard is intended to serve as a supplement to AISI S100 [CSA S136], (AISI, 2012a; CSA, 2012). The provisions provided in Chapter E are also intended to be used in conjunction with the other chapters of the Standard.

E2 Truss Responsibilities

The Standard adopts Section II of AISI S202 (AISI, 2011a) for the responsibilities of the individuals and organizations involved in the design, fabrication and installation of cold-formed steel trusses. Alternate provisions as agreed upon by the involved parties are permitted.

E3 Loading

The Standard does not establish the appropriate loading requirements for which a truss should be designed. In most cases, these loads are adequately covered by the applicable building code or standard.

E4 Truss Design

The provisions contained in this section of the Standard address the various design aspects related to truss strength. The strength determinations required by the Standard are in accordance with either the Allowable Strength Design (ASD), Load and Resistance Factor Design (LRFD) or Limit States Design (LSD) methods given by AISI S100 [CSA S136], (AISI, 2012; CSA, 2012), except where additional research studies have indicated an alternative approach is warranted.

E4.3 Analysis

The structural analysis requirements contained in the Standard are based on available information pertaining to the behavior of cold-formed steel C-shaped section truss assemblies (Harper, 1995; LaBoube and Yu, 1998). These requirements do not preclude the use of more rigorous analysis or design assumptions as determined by rational analysis or testing.

E4.4 Member Design

E4.4.1 Properties of Sections

AISI S100 [CSA S136] has been shown to be highly reliable for determining the design cross-section properties of C-shapes and other simple geometries. For more complex shapes, such as those utilizing longitudinal stiffeners, AISI S100 [CSA S136] Direct Strength Method design provisions may be used to estimate the load-carrying capacity. Tests in accordance with Section F1 of AISI S100 [CSA S136] can also be used.
E4.4.2 Compression Chord Members

When subjected to gravity load, the compression chord member may experience the combined effects of bending and axial compression. The design for combined load effects is governed by Section C5.2 of AISI S100 [CSA S136].

Engineering design specifications recognize the need for using rational analysis or test to define an effective length factor. The Standard permits the use of either rational analysis or testing.

Based on research on C-shaped section trusses conducted at the University of Missouri-Rolla (UMR) (Harper, 1995; Ibrahim, 1998), it was determined that the unbraced lengths, $L_x$ and $L_y$, may be taken as equal to the distance between the panel points. It was also discovered that where structural sheathing is attached to the chord member and where the compression chord member is continuous over at least one intermediate panel point, and is continuous from the heel to the pitch break, heel to heel (in the case of a parallel chord truss), or breakpoint of a truss, $L_y$ may be taken as the distance between sheathing connectors. Engineering judgment indicates that where sheathing is not attached to the top chord member, $L_y$ may be taken as the distance between panel points.

In the cold-formed steel truss industry, the sheathing is used as a structural component and the connection spacing of the sheathing to the cold-formed steel member is a design consideration. Therefore, sheathing connector spacing is indeed a structural requirement, and that is why the spacing of the connector is used when designing the truss chords for compression when there is structural sheathing applied.

The UMR research also determined that for a structurally sheathed C-shaped section truss where the compression chord member is continuous over at least one intermediate panel point, and is continuous from the heel to the pitch break, or breakpoint of a truss, $K_x$, $K_y$, and $K_t$ may be taken as 0.75. For other compression chord members, based on engineering judgment, $K_x$, $K_y$, and $K_t$ should be taken as unity.

An alternative design assumption for chord members in compression, based on engineering practice and judgment, is to assume that the effective length be taken as the distance between two adjacent points of contraflexure. In such case, the effective length factor and $C_m$ should be taken as unity.

The required effective length factors and unbraced lengths given in the Standard for hat-shapes are based on engineering judgment. The Z-shape requirements are based on proprietary testing.

Consistent with AISI S100 [CSA S136], the end moment coefficient, $C_m$, should be taken as 0.85, unless a more rigorous analysis is performed to justify another value.

Requirements in the Standard for the evaluation of the bending strength [resistance] are based on engineering judgment.

Ibrahim et al. (1998)- determined that when a C-shaped section compression chord member is subject to concentrated load at a panel point, the interaction of axial compression, bending and web crippling must be considered. The researchers proposed the following ASD interaction equation:

$$\frac{P}{P_{no}} + \frac{M}{M_{nso}} + \frac{R}{R_n} \leq \frac{1.49}{\Omega}$$

(Eq. C-E4.4.2-1)

where

$P$ = Compression axial load
M  = Bending moment
R  = Concentrated load
$P_{no}$ = Nominal axial strength [resistance] computed at $f = F_y$
$M_{n\text{xo}}$ = Nominal flexural strength [resistance] computed at $f = F_y$
$R_n$ = Nominal interior one-flange web crippling strength [resistance]
$\Omega$ = Safety factor
$= 1.95$

The values of $P$ and $M$ are to be determined by structural analysis for the panel point in question, where $R$ is the applied concentrated load at the panel point. The nominal strengths [resistances] are to be computed using AISI S100 [CSA S136]. Based on a statistical analysis consistent with load and resistance factor design, the safety factor was determined. The Standard also includes a similar equation applicable to the LRFD and LSD methods.

### E4.4.3 Tension Chord Members

The design requirements prescribed by the Standard for tension chord members are based on experience and engineering judgment.

### E4.4.4 Compression Web Members

The behavior of a compression web member is a function of the connection of the web member to the chord member. For example, a common connection detail of C-shaped chord and web members is to attach the respective members back-to-back through their webs. Such a connection detail creates an eccentric loading condition in the web member. When an axial load is applied to a truss web member in this type of truss construction, this eccentric loading condition will produce a bending moment in the member that is acting out-of-plane to the truss. This bending moment needs to be analyzed using Section E4.4.4 of this Standard. In addition to the check in this Standard, a compression web member is to be analyzed with the axial load alone using Section C4 of AISI S100 [CSA S136].

Researchers at the University of Missouri-Rolla (Rieman, 1996; Ibrahim et al., 1998) determined that for a C-shaped compression web member that is attached through its web element, the interaction of axial compression and out-of-plane bending may be determined by the following ASD interaction equation:

$$\frac{\Omega_{\text{b}} R P_{\alpha}}{P_{n}} + \frac{\Omega_{\text{m}} C_{\text{my}}} {M_{\text{mx}} \alpha_y} \leq 1.0$$

(C-E4.4.4-1)

where

$$R = -\left(\frac{L/r}{173}\right)^2 + \frac{L/r}{88} - 0.22 \geq 0.6$$

(C-E4.4.4-2)

$L$ = Unbraced length of the compression web member
$r$ = Radius of gyration of the full section about the minor axis
$P_n$ = Nominal axial strength [resistance] based on Section C4.1 of AISI S100 [CSA S136]. Only flexural buckling need be considered.
$e$ = Eccentricity of compression force with respect to the centroid of the full section of the web member

Other variables are defined in Section C5.2.1 of AISI S100 [CSA S136].

The parameter, $R$, is an experimentally determined reduction imposed on the axial load. The equation is a fit to the average test data, which is a common practice in cold-formed steel research. To recognize the lower limit on the tested $L/r$ ratio, the Standard...
stipulates $R \geq 0.6$. The intent of $R$ is to recognize the increased significance of the bending effect, compared to the axial effect for longer length web members. Unique to the application of the interaction equation is the determination of the nominal axial strength [resistance] based on flexural buckling alone. Research showed that the minor axis bending, which resulted from the eccentrically applied axial load, created a member deflection that enabled only flexural buckling. Thus, the behavior of the web member was determined predominately by bending resulting from the eccentric load. The parameters $P$, $\Omega_b$, $\Omega_c$, $C_{my}$, $M_{ny}$ and $\alpha_y$ are defined in accordance with Section C5.2.1 of AISI S100 [CSA S136]. The Standard also includes a similar equation applicable to the LRFD and LSD methods.

For compression web member cross-sections other than a C-shape attached through its web element, which has symmetry of loading, the axial compression load may be taken as acting through the centroid of the section.

When computing the available strength [factored resistance], the effective lengths, $K_xL_x$, $K_yL_y$ and $K_tL_t$, may be taken as the distance between the centers of the member’s end connection patterns. This assumption is consistent with the analysis approach used by UMR researchers (Rieman, 1996; Ibrahim et al., 1998).

### E4.4.5 Tension Web Members

Tension web members may experience a reduction in load-carrying capacity when subjected to combined axial load and bending. For C-shaped sections, this may be attributed to the dominant behavior being that of bending resulting from the eccentric load. However, testing has not documented that the combined loading compromises the integrity of the tension member. Therefore, for a tension web member connected to the web element of a chord member, or connected to a gusset plate, the Standard permits the axial tension load to be taken as acting through the centroid of the web member’s cross-section.

### E4.4.6 Eccentricity in Joints

The Standard does not specify the use of a multiple or single node structural analysis model to account for the effects of eccentricity in joints. The truss stiffness will differ based on whether a multiple or single node analysis is performed. When a multiple node analysis is used, a node should be placed at each web member location where the center line of the web member meets the center line of the chord member. When performing a single node analysis, additional design considerations may be necessary. For example, eccentricity created by the spatial relationship of the web members and the chord member at a joint may generate additional moments, shears, and/or axial forces. Such moments and forces may be directly reflected in a multiple node analysis model. Thus, when using a single node analysis model, a secondary analysis and design check of the joint, or a load test may be required to justify the design.

The Standard defines a web member lap length as 75% of the chord member depth. This minimum lap length is assumed, based on engineering judgment, to serve as a web shear stiffener for the chord member. The chord member segment between the assumed stiffeners is to be investigated for combined bending and shear, where a stiffened shear panel is assumed, in accordance with Equation C3.3.1-2 of AISI S100 [CSA S136]. For truss configurations having the web member lap length less than 75% of the chord member’s depth, the chord member is to be investigated for combined bending and shear in accordance with Equation C3.3.1-1 of AISI S100 [CSA S136]. Refer to Figures C-E4.4.6 (a) and C-E4.4.6 (b) for a pictorial definition of the term “web member lap length” for two configurations of a truss.
web member and truss chord member connection. Rational design assumptions for this “web member lap length” must be used when other connection geometries are encountered.

Along the length of the chord member, at the mid-point between the intersecting web members, shear is to be evaluated by Section C3.2 of AISI S100 [CSA S136]. The shear buckling coefficient is taken to be consistent with the assumed shear panel condition at the segments’ ends as defined by Section C3.2 of AISI S100 [CSA S136].

Based on experience, where screws are used as the connector, a minimum of four screws should be used in a web member to chord member connection and the screws should be equally distributed in their group.

![Web Member Lap Length for Flat Truss Chord](image)

![Web Member Lap Length for Sloped Truss Chord](image)

**E4.5 Gusset Plate Design**

To establish a design methodology for thin gusset plate connections in compression, a testing program consisting of 49 specimens was conducted at the University of Missouri-Rolla (Lutz, 2004). Two separate models were developed to predict the capacity of the plates. Both plate buckling and column buckling models were studied. Although both models are sufficient for calculating the strength [resistance] of the gusset plates, it was recommended that
the plate-buckling model be used in design. The plate-buckling model, assuming \( f = f_y \), \( k = 4 \) and \( w = W_{\text{min}} \), provided a better correlation to the test data. A limited number of tests were performed to determine the strength gain in gusset plates with edge stiffeners. The results of tests in which both edges of the gusset plate parallel to the applied load had edge stiffeners showed an approximate strength increase of 25% for the plates.

The gusset plate design provisions in the Standard require that \( W_{\text{min}} \) be taken as the lesser of the actual gusset plate width or the Whitmore section, which defines a theoretically effective cross-section based on a spread-out angle of 30° along both sides of the connection, beginning at the first row of fasteners in the connection. The first row of fasteners is defined as the row of fasteners that is the furthest away from the section of gusset plate being considered. Figure C-E4.5-1 illustrates how \( W_{\text{min}} \) can be determined for a typical fastener pattern connecting a truss chord member to a gusset plate at a typical pitch break connection at the ridge of a roof truss. Determining \( W_{\text{min}} \) for other conditions would be analogous.

![Figure C-E4.5-1 Whitmore Plate Width](image)

The gusset plate design provisions in the Standard require that \( L_{\text{eff}} \) be taken as the average length between the last rows of fasteners of adjacent truss members. Figure C-E4.5-2 illustrates how \( L_{\text{eff}} \) can be determined for a typical pitch break connection at the ridge of a roof truss. Determining \( L_{\text{eff}} \) for other conditions would be analogous.

For gusset plates in tension, reference is made to the requirements of AISI S100 [CSA S136]. These requirements include checks on the gross and net areas of the gusset plate, shear lag and group or tear-out of fasteners. Engineering judgment is required to determine the portion of the gusset plate to be included in the gross and net area checks.
E4.6 Connection Design

E4.6.1 Fastening Methods

Although the common fastening system used by the industry is the self-drilling screw, the Standard permits the use of bolts, welds, rivets, clinches, and other technologies as approved by the truss designer. Screw, bolt, and weld connections are to be designed in accordance with AISI S100 [CSA S136]. If other fastener types, such as rivets, clinches, rosettes, adhesives, etc., are to be used in the fabrication of the truss, the design values are to be determined by tests, and the available strength [factored resistance] determined in
accordance with Section F1 of AISI S100 [CSA S136].

For the design of connecting elements, such as plates, gusset plates, and brackets, reference is made to AISI S100 [CSA S136], which in turn makes reference to Section J4 of AISC 360 (AISC, 2010).

**E4.6.2 Coped Connections for C-Shaped Sections**

The design engineer should give special attention to the heel and pitch break connections of the truss to ensure structural integrity of the truss.

At a pitch break, coped members may be reinforced to prevent web buckling of the chord member. Attachment of a track section of the same thickness as the chord member, thus creating a box section, and having a length equal to the depth of the chord member has been shown to provide adequate reinforcement (Ibrahim, 1998). Lateral bracing is also important to stabilize the pitch break from overall buckling. At the heel, a bearing stiffener may be needed to preclude web crippling (Koka, 1997).

At a heel connection, UMR research (Koka, 1997) determined that coping reduces both the shear buckling and web crippling strength [resistance] of the coped bottom chord member. The UMR research proposed that where a coped flange had a bearing stiffener with a minimum moment of inertia ($I_{\text{min}}$) of 0.161 in.$^4$ (67,000 mm$^4$), the shear strength [resistance] could be calculated in accordance with AISI S100 [CSA S136] Section C3.2, but required a reduction as defined by the following factor, $R$:

$$R = 0.976 + \frac{0.556c}{h} - \frac{0.532d_c}{h} \leq 1.0 \quad (\text{C-E4.6.2-1})$$

The cited limits in the Standard reflect the scope of the experimental study and apply only to connections where the bottom chord member is coped.

Where a bearing stiffener not having the minimum moment of inertia is used, web crippling controlled the heel connection strength [resistance] (Koka, 1997). Therefore, the Standard requires that the computed end one-flange loading web crippling strength [resistance] at the heel, as determined by AISI S100 [CSA S136] Section C3.4 be reduced by the following factor:

$$R = 1.036 + \frac{0.668c}{h} - \frac{0.0505d_c}{h} \leq 1.0 \quad (\text{C-E4.6.2-2})$$

The cited limits in the Standard reflect the scope of the experimental study.

Where $c =$ length of cope and $d_c =$ depth of cope as illustrated in Figure C-E4.6.2-1. $I_{\text{min}}$ of the stiffener is computed with respect to an axis parallel to the web of the bottom chord member.
E4.7 Serviceability

Serviceability limits are to be chosen based on the intended function of the structure, and should be evaluated based on realistic loads and load combinations as determined by the building designer. Because serviceability limits depend on the function of the structure and the perception of the occupant, it is not possible to specify general limits in the Standard. As a guide to the designer, the maximum allowable deflection of the chord member of a truss resulting from gravity load, excluding dead load, may be taken as the following:

(a) Span/360 for plaster ceilings
(b) Span/240 for flexible type ceilings
(c) Span/180 for no finished ceiling
(d) Span/480 for floor systems

Although the use of a deflection limit has been used to preclude vibration problems in the past, some floor systems may require explicit consideration of the dynamic characteristics of the floor system.

Truss serviceability is evaluated at nominal [specified] load. When computing truss deflections, the Standard permits the use of the full cross-sectional area of the truss members. The use of full areas is warranted because a truss system is a highly indeterminate structural system, and local buckling of an individual member does not appreciably affect the stiffness of the truss at design load.

E5 Quality Criteria for Steel Trusses

The practices defined herein have been adopted by the Standard as commonly accepted practice. In the absence of other instructions in the contract documents, the provisions of Chapter E4 are the quality standard for the manufacturing processes of steel trusses to be used in conjunction with an in-plant quality assurance procedure and a truss design.
E6 Truss Installation

*Cold-formed steel trusses* are planar structural components. The structural performance depends on the *trusses* being installed vertically, in-plane, at specified spacing, and being properly braced. The installer is responsible for receipt, storage, erection, installation, field assembly, and bracing. The practices defined herein have been adopted by the Standard as commonly accepted practice.

A maximum bottom chord permanent lateral restraint and brace spacing of 10 feet is suggested, based on field experience and limited testing.

**E6.1.1 Straightness**

The *truss* installation tolerances defined in Section E6.1.1 have been used for many years in the prefabricated *truss* industries of both *cold-formed steel* and wood with good success. The tolerances listed in this section are *truss* assembly tolerances and not individual member tolerances. Member tolerances are outlined in the Standard. *Cold-formed steel trusses* are typically used with structural sheathing applied to the top chord. This sheathing is designed to support lateral loads and act as a diaphragm. This diaphragm system behavior for *trusses* with the structural sheathing is what also enables the adoption of a seemingly more liberal out-of-straightness.

**E6.1.2 Plumbness**

The *truss* installation tolerances defined in Section E6.1.2 have been used for many years in the prefabricated *truss* industries of both *cold-formed steel* and wood *trusses*.

E7 Test-Based Design

Design calculations require the application of *approved* materials and cross-section properties. When calculations are used to define the structural performance of a *truss* assembly, the structural performance may be verified by full-scale test. However, when the structural performance cannot be determined by calculation, the structural performance must be determined by test. Appendix 2 of this Standard provides guidance for both component and full-scale load tests.
F. TESTING

In 2015, Chapter F was created to allow reference to applicable AISI S900-series test standards.

F1 General

Section F1 lists all the AISI S900-series test standards that are deemed to be generally applicable to cold-formed steel structural framing applications.

F2 Truss Components and Assemblies

In 2015, methods for testing truss components and assemblies, formerly in AISI S214 Chapter G, were moved to Appendix 2.
APPENDIX 1, CONTINUOUSLY BRACED DESIGN FOR DISTORTIONAL BUCKLING RESISTANCE

Calculation of the nominal distortional buckling strength in flexure and in compression in accordance with AISI S100 [CSA S136] may utilize the beneficial system effect of sheathing fastened to the compression flange(s) of floor joists, ceiling joists, and roof rafters through the calculation of the rotational stiffness provided to the member, \( k_\phi \). It is also permissible, and indeed conservative, to ignore this beneficial restraint and assume \( k_\phi = 0 \).

Testing was conducted to determine the provided rotational restraint in typical framing systems (Schafer et al. 2007, 2008). From this testing it was determined that the sheathing rotational restraint could be divided into two parts: one from the sheathing and one from the connector. For the sheathing industry, standard values as provided by the APA, Panel Design Specification (APA, 2004) and the Gypsum Association (GA, 2001) are provided. As reported in Schafer et al. (2007, 2008), the gypsum board provided stiffness in-line with or exceeding reported values; but the deformation capacity was severely limited; therefore, it was determined that gypsum board should only be relied upon in a serviceability check, not for strength limit states. Currently, only the Direct Strength Method of AISI S100 Appendix 1 provides a serviceability methodology for distortional buckling; therefore, the design method specifically references Appendix 1 for checking serviceability with gypsum board. For the connector, the experimentally determined values are fit to a simple empirical expression and then provided in tabular form. The testing was conducted with fasteners at 12 in. (305 mm) o.c.; therefore, the Standard requires that this fastener spacing (or less) be maintained.

Design examples and design aids for the application of these methods to floor joists are provided in CFSEI Technical Note G100-08 (Schafer, 2008).
APPENDIX 2, TEST METHODS FOR TRUSS COMPONENTS AND ASSEMBLIES

2.1 Component Structural Performance Load Test

The load test procedures contained in the Standard may be used to confirm or define the design methodology for a chord member or a web member of a truss assembly. This test protocol is intended for use in the testing of truss assembly components fabricated using cold-formed steel structural members.

Because the flexural strength [resistance] of a truss member may be bending (yielding or buckling), shear, web crippling, or combinations thereof, this test protocol defines what should be considered in regard to a test, but does not define for the testing agency how to do the test. This leaves the selection of the test fixture and loading medium to the discretion of the testing agency. For details of test apparatus and procedures that have been used for such purposes, but in no way should be regarded as mandatory, see Hetrukul and Yu (1978), LaBoube and Yu (1978a, 1978b, 1982), and Yu (2000).

This protocol also outlines the procedures to be followed to define the compression strength [resistance] of a truss component for static load. Because the compression strength [resistance] of a truss component may be local buckling or overall column buckling, this procedure defines what to do in regard to performing a test, but does not tell the testing agency how to do the test. This leaves the selection of the test fixture and loading medium to the discretion of the testing agency. It is the responsibility of the design professional to determine the appropriate loading rate.

Load tests can be hazardous to the individuals performing or observing the tests, and also can damage the testing fixtures or the structure housing the test setup due to a sudden release of stored energy at failure. Care should be exercised in the preparation of the test setup to ensure that the failure of a test specimen will not result in a secondary collapse of a structural element not involved in the test.

The number of similar components that should be tested will vary with the desired precision and reliability of the information to be obtained and with the purpose of the test.

Loads may be measured using one or more of the following devices. Pressure gages or load cells can be incorporated into a hydraulic loading system. These devices must be calibrated with the jacks or cylinders at different positions of piston travel to ensure a true loading history.

Deflection readings may be taken in a variety of ways. One of the simplest methods is by the use of a taut wire or monofilament line stretched between supports in combination with a mirror-scale located at the desired deflection measurement points. When the taut wire method is used, care must be taken to ensure that the wire will remain under tension during the entire test. This can be accomplished by incorporating a spring into the line or by letting one end run over a pulley with a weight attached to the line. Deflections are read on a scale with a mirror backing. The mirror-scale deflection measurement device is read by visually lining up the top of the wire with its image on the mirror and then reading the scale.

Other commonly used deflection measurement devices are such things as direct reading micrometer dial gages, optical levers used to read scales attached to the truss, linearly variable differential transformers (LVDT), or a combination of flexible wire attached at deflection points and monitored remotely through a system of pulleys attached to dial gages.

2.2 Full-Scale Confirmatory Load Test

This test protocol is intended for use in the testing of truss assemblies fabricated using cold-
formed steel structural members and connections. A confirmatory test is performed with the intent to verify structural performance as defined by calculations in accordance with a recognized specification or standard. Because design was in accordance with a specification or standard, all that is needed is that the tested specimen demonstrates strength [resistance] not less than the applicable calculated strength [resistance].

The test protocol does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this protocol to establish appropriate safety and health practices and determine the applicability of regulatory limitation prior to use.

A full-scale truss test is the test of a structural system. It is generally accepted that a safety factor of 1.5 is for overload and nothing above it should be expected in an in-situ test since the other uncertainties may already have been used up. If the test is conducted under laboratory conditions, 1.65 is a reasonable safety factor since fabrication and erection uncertainties are minimized. This factor of 1.65 is consistent with the recommendations of the Steel Joist Institute.

This protocol outlines the procedures to be followed in the static load testing of load-carrying truss assemblies. While the procedure tells what to do, it does not tell the testing agency how to do it. This leaves the selection of the test fixture and loading medium to the discretion of the testing agency. It is the responsibility of the design professional to determine the appropriate loading rate.

Full-scale load tests of any large-size specimen such as a truss can be hazardous to the individuals performing or observing the tests, and also can damage the testing fixtures or the structure housing the test setup due to a sudden release of stored energy at failure. Care should be exercised in the preparation of the test setup to ensure that the failure of a test specimen will not result in a secondary collapse of a structural element not involved in the test.

The test fixture and load application means should be designed with adequate strength [resistance] and stiffness to ensure that it is the test specimen that is being tested and not the test fixture.

In a single truss test, frequently the support at one end will allow rotation but not translation (a rocker) and the other will allow both rotation and translation (a roller) so as not to induce additional unintentional secondary stresses into the test truss as it deforms under load.

The loading devices should result in the desired truss-loading situation regardless of whether uniform, concentrated, or a combination of both. The loading system should be such as to allow the application of loads during the test to approximate the overall intended in-service load distribution. Care should be taken to avoid eccentrically applied loads unless this type of loading is desired.

2.3 Full-Scale Structural Performance Load Test

This test protocol is intended for use in the testing of truss assemblies fabricated using cold-formed steel structural members and connections when calculation of the safe strength [resistance] cannot be made in accordance with recognized calculation design specifications or standards.
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Advisory Note: The Light Gauge Steel Engineers Association (LGSEA) in 2006 changed its name to the Cold-Formed Steel Engineers Association (CFSEI). CFSEI is located at AISI headquarters in Washington, DC.