AISI STANDARD

North American Standard for Seismic Design of Cold-Formed Steel Structural Systems

2015 Edition With Supplement 1
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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 seismic design for cold-formed steel structures. 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 on the Standard.

With anticipated improvements in understanding of the behavior of cold-formed steel 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 registered professional engineer. Indeed, in many jurisdictions, such a 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

The American Iron and Steel Institute (AISI) Committee on Framing Standards has developed this first edition of the *North American Standard for Seismic Design of Cold-Formed Steel Structural Systems* (hereinafter referred to as this *Standard* in general) in 2015. This *Standard* is intended to address the design and construction of cold-formed steel structural members and connections used in the seismic force-resisting systems in buildings and other structures. In this first edition, the material represents a merging of AISI S110, *Standard for Seismic Design of Cold-Formed Steel Structural Systems – Special Bolted Moment Frames*, 2007 Edition with Supplement No. 1-09, and the seismic portions of AISI S213, *North American Standard for Cold-Formed Steel Framing – Lateral Design*, 2007 Edition with Supplement No. 1-09. In addition, many of the seismic design requirements stipulated in this *Standard* are drawn from ANSI/AISC 341-10, *Seismic Provisions for Structural Steel Buildings*, developed by the American Institute of Steel Construction (AISC). The application of this *Standard* should be in conjunction with AISI S100, *North American Specification for the Design of Cold-Formed Steel Structural Members* (hereinafter referred to as AISI S100), and AISI S240, *North American Standard for Cold-Formed Steel Framing* (hereinafter referred to as AISI S240).

The Lateral Design Subcommittee of the AISI Committee on Framing Standards is responsible for the ongoing development of this *Standard*. The AISI Committee on Framing Standards gives the final approval of this document through an ANSI-accredited balloting process. The membership of these committees follows this Preface.

The Committee acknowledges and is grateful to the numerous engineers, researchers, producers and others who have contributed to the body of knowledge on these subjects. AISI further acknowledges the permission of the American Institute of Steel Construction for adopting many provisions from its *Seismic Provisions for Structural Steel Buildings*.

In this first edition of AISI S400, special recognition is extended to Hank Martin, Sr. who served as AISI’s West Coast Regional Director of Construction Codes and Standards from 1982 to 2006. Hank was pivotal in the initial adoption of cold-formed steel lateral design into the model building codes. His vision for the industry led to the establishment of the AISI Committee on Framing Standards in 1998, the development of AISI S213 in 2004, and, eventually, to the publication of AISI S110 in 2009.

Building on the work initiated by Hank, the AISI S400 Working Group spent the past two years developing the new combined seismic standard, AISI S400. The committee would like to thank the members of the AISI S400 Working Group, which includes Rob Madsen, Ben Schafer, Colin Rogers, and J.R. Mujagic, for their herculean job. Additionally, the committee would like to thank Shahab Torabian, Randy Shackelford and Roger LaBoube for their contributions to the document.

In the second printing of this standard, Supplement 1 to AISI S400-15 is incorporated.

American Iron and Steel Institute
November 2015
Updated September 2016
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NORTH AMERICAN STANDARD FOR SEISMIC DESIGN OF COLD-FORMED STEEL STRUCTURAL SYSTEMS
WITH SUPPLEMENT 1

A. GENERAL

A1 Scope and Applicability

A1.1 Scope

This Standard is applicable for the design and construction of cold-formed steel structural members and connections in seismic force-resisting systems and diaphragms in buildings and other structures.

A1.2 Applicability

A1.2.1 This Standard shall be applied in conjunction with AISI S100 [CSA S136], AISI S240 and the applicable building code.

A1.2.2 In the absence of an applicable building code, the design requirements shall be in accordance with accepted engineering practice for the location under consideration as specified by the applicable sections of ASCE 7 in the U.S. and Mexico, or the National Building Code of Canada (NBCC) in Canada.

A1.2.3 In the U.S. and Mexico, in seismic design categories B or C and where the seismic response modification coefficient, R, used to determine the seismic design forces is taken equal to 3, the cold-formed steel structural members and connections in lateral force-resisting systems need only be designed in accordance with AISI S100 or AISI S240, as applicable.

In Canada, where the seismic force modification factors, RdR₀, used to determine the seismic design forces, are taken as less than 1.56 or the design spectral response acceleration S(0.2) as specified in the NBCC is less than or equal to 0.12, the cold-formed steel structural members and connections in lateral force-resisting systems need only be designed in accordance with CSA S136 or AISI S240, as applicable.

User Note:

This Standard intends to exempt lateral force-resisting systems only where the seismic design category is B or C and the seismic response modification coefficient, R, equals 3. ASCE 7, Table 12.2-1, Line H exempts these steel systems from seismic detailing requirements in this Standard as long as they are designed in accordance with AISI S240 or AISI S100, as applicable. For seismic design category A, it is not necessary to define a seismic force-resisting system that meets any special requirements and this Standard does not apply.

User Note:

In Canada, the NBCC sets the seismic force modification factors, RdR₀, for “Other Cold-Formed Steel Seismic Force-Resisting System(s)” equal to 1.0, which is the only system with RdR₀ under 1.56. Systems falling into this category need only be designed in accordance with CSA S136 or AISI S240 as appropriate.

A1.2.4 Elements not specifically addressed by this Standard shall be constructed in accordance with applicable building code requirements.

A1.2.5 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.

**A1.2.6** This *Standard* includes Chapters A through H and Appendix 1 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. Where a country is indicated in square brackets following the definition, the definition shall apply only in the country indicated. Terms included in square brackets shall be specific to LSD terminology. Terms not defined in Section A2.1 shall have the ordinary accepted meaning for the intended context.

**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]

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

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

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

**Authority Having Jurisdiction.** The organization, office, or individual responsible for enforcing the requirements of this *Standard*, or for approving materials, an installation, or a procedure.

**User Note:**

In Canada, the regulatory authority functions as the authority having jurisdiction. It is defined as the federal, provincial/territorial, or municipal ministry, department, board, agency, or commission that is responsible for regulating by statute the use of products, materials, or services.

**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 (Local Compressive).** Limit state of local compressive yielding due to the action of a member bearing against another member or surface.

**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 support to the studs in a shear wall.

**Boundary Elements.** Portions along wall and diaphragm edges for transferring or resisting forces. Boundary elements include chords and collectors (drag struts) at diaphragm, strap braced wall and shear wall perimeters, edges of openings, discontinuities and re-entrant corners.

**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.

Capacity-Based Design. Design of lateral force-resisting systems according to capacity design principles to resist the maximum anticipated seismic loads.

**User Note:**
Capacity design principles for design of a seismic force-resisting system include all of the following:

a) specific elements or mechanisms are designed to dissipate energy; b) all other elements are sufficiently strong for this energy dissipation to be achieved; c) structural integrity is maintained; d) elements and connections in the horizontal and vertical load paths are designed to resist these seismic loads and corresponding principal and companion loads as defined by the NBCC; e) diaphragms and collector elements are capable of transmitting the loads developed at each level to the vertical seismic force-resisting system; and f) these loads are transmitted to the foundation.

[Canada]

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

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.

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 or seismic force-resisting system.

Component. See Structural Component.

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.

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.

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).

Design Earthquake. The ground motion represented by the design response spectrum as specified in the applicable building code.

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 Story Drift. Calculated story drift, including the effect of expected inelastic action, due to design level earthquake forces as determined by the applicable building code.
Designated Energy Dissipating Mechanism. Selected portion of the seismic force-resisting system designed and detailed to dissipate energy.

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 seismic force-resisting system. [USA and Mexico]

Diaphragm. Roof, floor or other membrane or bracing system that transfers in-plane forces to the wall elements as part of the seismic force-resisting system. [Canada]

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.

Hold-Down (Tie-Down). A device used to resist overturning forces in a shear wall, strap braced wall, or uplift forces in a cold-formed steel structural member. For the purposes of this Standard, it is a component of the seismic force-resisting system.

Joint. Area where two or more ends, surfaces or edges are attached. Categorized by type of fastener or weld used and the method of force transfer.

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.

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 resistance is the maximum load-carrying capacity. Limit states that restrict the intended use of a member for reasons other than safety are called serviceability limit states. [Canada]

User Note:
Ultimate limit states include overturning, sliding, fracturing, and exceeding load-carrying capacity. Serviceability limit states include deflection, vibration, and permanent deformation.

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]

Lip. That part of a structural member 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. A factor defined by the applicable building code to take into account the variability in loads and the analysis of their effects. [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]

Moment Frame. Framing system that provides resistance to lateral loads and provides stability to the structural system primarily by shear and flexure of the structural members and their connections.

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.

Owner’s Representative. The owner or individual designated contractually to act for the owner.

Other Structures. Structures designed and constructed in a manner similar to buildings, with building-like vertical and lateral load-resisting elements.

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.

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.

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

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.

Safety Factor (\(\Omega\)). 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 on its risk category and the severity of the design earthquake ground motion at the site. [USA and Mexico]

Seismic Force Modification Factors, \( R_d \) and \( R_o \). Factors that reduce seismic load effects to strength level for ductility and overstrength respectively, as specified by the applicable building code. [Canada]

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

Seismic Response Modification Coefficient, \( R \). Factor that reduces seismic load effects to strength level as specified by the applicable building code. [USA and Mexico]

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.

Snug-Tightened Bolt. Bolt in a joint in which tightness is attained by either a few impacts of an impact wrench, or the full effort of a worker with an ordinary spud wrench, that brings the connected plies into firm contact.

Specified Minimum Yield Stress. Lower limit of yield stress specified for a material as defined by ASTM.

Specified Minimum Tensile Strength. Lower limit of tensile strength specified for a material as defined by ASTM.

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. Wall designed to resist in-plane lateral forces that is braced by strap bracing and is provided with hold-downs and anchorage at each end of the wall segment.

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.

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.

Type I Shear Wall. Wall designed to resist in-plane lateral forces that is fully sheathed and that is provided with hold-downs and anchorage 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 and anchorage 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.

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.

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.

A3 Materials

A3.1 Material Specifications

Structural members utilized in cold-formed steel seismic force-resisting systems shall be manufactured from steel complying with the requirements of one of the following ASTM specifications, subject to the additional limitations specified in Chapter E and Chapter F:

ASTM A36/A36M, Standard Specification for Carbon Structural Steel
ASTM A242/A242M, Standard Specification for High-Strength Low-Alloy Structural Steel
ASTM A283/A283M, Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates
ASTM A500 (Grade B or C), Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A529/A529M, Standard Specification for High-Strength Carbon-Manganese Steel of Structural Quality
ASTM A572/A572M (Grade 42 (290), 50 (345), or 55 (380)), Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
ASTM A588/A588M, Standard Specification for High-Strength Low-Alloy Structural Steel With 50 ksi [345 MPa] Minimum Yield Point to 4-in. [100 mm] Thick
ASTM A653/A653M (SS Grades 33 (230), 37 (255), 40 (275), and 50 (340) Class 1 and Class 3; HSLAS Types A and B, Grades 40 (275), 50 (340), 55 (380) Class 1 and 2, 60 (410)), Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM A792/A792M (Grades 33 (230), 37 (255), 40 (275), and 50 Class 1 (340 Class 1)), Standard Specification for Steel Sheet, 55% Aluminum-Zinc Alloy-Coated by the Hot-Dip Process
ASTM A875/A875M (SS Grades 33 (230), 37 (255), 40 (275), and 50 (340) Class 1 and Class 3; HSLAS Types A and B, Grades 50 (340), 60 (410)), Standard Specification for Steel Sheet, Zinc-5% Aluminum Alloy-Coated by the Hot-Dip Process
ASTM A1003/A1003M (Grades ST33H, ST37H, ST40H, ST50H), Standard Specification for Steel Sheet, Carbon, Metallic- and Nonmetallic-Coated for Cold-Formed Framing Members
ASTM A1008/A1008M (SS Grades 25 (170), 30 (205), 33 (230) Types 1 and 2, and 40 (275) Types 1 and 2; HSLAS Classes 1 and 2, Grades 45 (310), 50 (340), 55 (380), 60 (410), and 65 (450)); HSLAS-F Grades 50 (340), 60 (410)), Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved
Formability, Solution Hardened, and Bake Hardenable

ASTM A1011/A1011M (SS Grades 30 (205), 33 (230), 36 (250) Types 1 and 2, 40 (275), 45 (310), 50 (340), and 55 (380); HSLAS Classes 1 and 2, Grades 45 (310), 50 (340), 55 (380), 60 (410), and 65 (450); HSLAS-F Grades 50 (340), and 60 (410)), Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy With Improved Formability

ASTM A1085, Standard Specification for Cold-Formed Welded Carbon Steel Hollow Structural Sections (HSS)

A3.2 Expected Material Properties

A3.2.1 Material Expected Yield Stress [Probable Yield Stress]

Where required in this Standard, the expected strength [probable resistance] of a connection or structural member shall be determined using the expected yield stress [probable yield stress], \( R_y \), with \( R_y \) given in Table A3.2-1, unless otherwise modified in Chapter E and Chapter F.

Values of \( R_y \), other than those listed in Table A3.2-1, are permitted to be used, if the values are determined by testing specimens representative of the product thickness and source, and such tests are conducted in accordance with the requirements for the specified grade of steel in Section A3.1.

<table>
<thead>
<tr>
<th>Steel</th>
<th>( R_y )</th>
<th>( R_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plates and bars: A36/A36M, A283/A283M</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>A242/A242M, A529/A529M, A572/A572M, A588/A588M</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Hollow Structural Sections: A500 Grade B</td>
<td>1.4</td>
<td>1.3</td>
</tr>
<tr>
<td>A500 Grade C</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>A1085</td>
<td>1.25</td>
<td>1.15</td>
</tr>
<tr>
<td>Sheet and strip (A606, A653/A653M, A792/A792M, A875, A1003/A1003M, A1008/A1008M, A1011/A1011M): ( F_y \leq 35 \text{ ksi (255 MPa)} )</td>
<td>1.5</td>
<td>1.2</td>
</tr>
<tr>
<td>( 37 \text{ ksi (255 MPa)} \leq F_y \leq 40 \text{ ksi (275 MPa)} )</td>
<td>1.4</td>
<td>1.1</td>
</tr>
<tr>
<td>( 40 \text{ ksi (275 MPa)} \leq F_y \leq 50 \text{ ksi (340 MPa)} )</td>
<td>1.3</td>
<td>1.1</td>
</tr>
<tr>
<td>( F_y \geq 50 \text{ ksi (340 MPa)} )</td>
<td>1.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

A3.2.2 Material Expected Tensile Strength [Probable Tensile Strength]

Where required in this Standard, the expected strength [probable resistance] of a connection or structural member shall be determined using the expected tensile strength [probable tensile strength], \( R_t \), with \( R_t \) given in Table A3.2-1, unless otherwise modified in Chapter E and Chapter F.
Values of $R_t$, other than those listed in Table A3.2-1, are permitted to be used, if the values are determined by testing specimens representative of the product thickness and source, and such tests are conducted in accordance with the requirements for the specified grade of steel in Section A3.1.

### A3.2.3 Material Modified Expected Yield Stress [Modified Probable Yield Stress]

Where required in this Standard, the expected strength [probable resistance] of a flexural member shall be determined from the modified expected yield stress [modified probable yield stress], $R_{re}R_{cf}R_yF_y$.

The factor to account for increase in yield stress above the nominal specified yield stress, $R_y$, shall be determined in accordance with Section A3.2.1.

The factor to account for the increase in yield stress due to cold work of forming, averaged over the cross section, $R_{cf}$, shall be taken as $F_{ya}/F_y$, where $F_{ya}$ is determined in accordance with Section A7.2 of AISI S100 [CSA S136]. $R_{cf}$ shall not be taken less than 1.1.

The factor considering the inelastic reserve capacity for a fully effective section in bending, $R_{re}$, shall be determined as follows:

For $\lambda < 0.673$,

$$R_{re} = \frac{M_{no}}{M_y} \quad (Eq. A3.2.3-1)$$

For $\lambda \geq 0.673$,

$$R_{re} = 1$$

where

$\lambda$ = Slenderness of compression flange of member considered, as defined in accordance with AISI S100

$M_{no}$ = Nominal strength [resistance] determined in accordance with Section C3.1.1(b) of AISI S100 [CSA S136], if applicable, or $M_y$

$M_y$ = Nominal flexural yield strength [resistance]

$$= S_fF_y \quad (Eq. A3.2.3-2)$$

where

$S_f$ = Full unreduced section modulus at yield stress, $F_y$

$F_y$ = Specified minimum yield stress

### A3.3 Consumables for Welding

All welds used in members and connections in the seismic force-resisting system shall be made in accordance with the requirements of AWS D1.1/D1.1M, AWS D1.3/D1.3M, Structural Welding Code – Sheet Steel, or CSA W59, as applicable, unless otherwise modified in Chapter E and Chapter F.

Electrodes shall be approved for use in resisting seismic forces.

### A4 Structural Design Drawings and Specifications

Structural design drawings and specifications shall indicate the work to be performed, and include items required by AISI S100 [CSA S136], AISI S240, the applicable building code, and the following, as applicable:
(a) Designation of the seismic force-resisting system,
(b) Identification of the structural members and connections that are part of the seismic force-resisting system, and
(c) Connection details between diaphragms and the elements of the seismic force-resisting system.

A5 Reference Documents

The following documents or portions thereof are referenced in this Standard and shall be considered part of the requirements of this Standard:

1. American Institute of Steel Construction (AISC), One East Wacker Drive, Suite 700, Chicago, IL 60601-1802:
   ANSI/AISC 341-10, Seismic Provisions for Structural Steel Buildings, June 22, 2010
   ANSI/AISC 360-10, Specification for Structural Steel Buildings, Chicago, IL, June 22, 2010
2. American Iron and Steel Institute (AISI), 25 Massachusetts Avenue, NW, Suite 800, Washington, DC 20001:
   AISI S100-12, North American Specification for the Design of Cold-Formed Steel Structural Members, 2012
   AISI S240-15, North American Standard for Cold-Formed Steel Structural Framing, 2015
3. American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia 20191-4400:
   ASCE/SEI 7-10 With Supplement 1-12, Minimum Design Loads for Buildings and Other Structures
4. ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959:
   ASTM A36/A36M-14, Standard Specification for Carbon Structural Steel
   ASTM A242/A242M-13, Standard Specification for High-Strength Low-Alloy Structural Steel
   ASTM A283/A283M-13, Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates
   ASTM A500-13, Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
   ASTM A529/A529M-14, Standard Specification for High-Strength Carbon-Manganese Steel of Structural Quality
   ASTM A572/A572M-15, Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
   ASTM A606-09a, Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, With Improved Atmospheric Corrosion Resistance
   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

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ASTM A1003/A1003M-15, Standard Specification for Steel Sheet, Carbon, Metallic- and Nonmetallic-Coated for Cold-Formed Framing Members
ASTM A1008/A1008M-15, Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy With Improved Formability, Solution Hardened and Bake Hardenable
ASTM A1011/A1011M-14, Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy With Improved Formability, and Ultra-High Strength
ASTM A1085-13, Standard Specification for Cold-Formed Welded Carbon Steel Hollow Structural Sections (HSS)
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 E2126-11, Standard Test Methods for Cyclic (Reversed) Load Test for Shear Resistance of Vertical Elements of the Lateral Force Resisting Systems for Buildings

5. American Welding Society (AWS), 8669 NW 36 Street, #130, Miami, Florida 33166-6672:
   AWS D1.1/D1.1M-2010, Structural Welding Code – Steel
   AWS D1.3/D1.3M-2008, Structural Welding Code – Sheet Steel

6. CSA Group, Mississauga, Ontario, Canada.
   CSA S16-09, Design of Steel Structures, 2009 Edition including Update No. 1 (2010), Update No. 2 (2010), Update No. 3 (2013)
   CSA S136-12, North American Specification for the Design of Cold-Formed Steel Structural Members
   CSA O325-07 (R2012), Construction Sheathing
   CSA O121-08 (R2013), Douglas Fir Plywood
   CSA O151-09 (R2014), Canadian Softwood Plywood
   CSA W59-13, Welded Steel Construction (Metal Arc Welding)

7. Department of Commerce Voluntary Product Standard, administered by NIST, Gaithersburg, MD
   DOC PS 1-09, Structural Plywood
   DOC PS 2-10, Performance Standard for Wood-Based Structural-Use Panels

8. National Research Council of Canada, Ottawa, Ontario, Canada
**B. GENERAL DESIGN REQUIREMENTS**

**B1 General Seismic Design Requirements**

**B1.1 General**

In the U.S. and Mexico, required strengths for the seismic force-resisting system shall be determined in accordance with the applicable building code. Seismic design parameters ($R, C_d, \Omega_o$), seismic design categories (SDCs), risk categories, design story drift, system limitations, and requirements for horizontal and vertical structural irregularities shall also be determined in accordance with the applicable building code.

In Canada, effect of factored load for the seismic force-resisting system shall be determined in accordance with the applicable building code. Seismic force modification factors ($R_d, R_o$), seismic design story drift, system limitations, and requirements for irregularities shall also be determined in accordance with the applicable building code, unless modified herein.

In the absence of an applicable building code, the design requirements 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 U.S. and Mexico, or the National Building Code of Canada in Canada.

**B1.2 Load Path**

Seismic load effects shall be resolved through a complete lateral force-resisting system using a continuous load path to the foundation.

**B1.3 Deformation Compatibility of Members and Connections Not in the Seismic Force-Resisting System**

Where deformation compatibility of structural members and connections that are not part of the seismic force-resisting system is required by the applicable building code, these elements shall be designed to resist the combination of gravity load effects and the effects of deformations occurring at the design story drift [seismic design story drift] calculated in accordance with the applicable building code.

**B1.4 Seismic Load Effects Contributed by Masonry and Concrete Walls**

Seismic load effects contributed by masonry and concrete walls are permitted to be resisted by the designated seismic force-resisting systems of this Standard subject to the limitations of Chapter E and Chapter F.

**B1.5 Seismic Load Effects From Other Concrete or Masonry Components**

Cold-formed steel structural members and connections are permitted to resist seismic forces from other concrete or masonry components, including, but not limited to, chimneys, fireplaces, concrete or masonry veneers, and concrete floors or roofs.

**B2 Lateral Force-Resisting System**

The complete lateral force-resisting system shall include one or more designated seismic force-
resisting systems, designed in accordance with Chapter E, and all other components required to ensure a continuous load path for the seismic loads. Combinations of seismic force-resisting systems shall be in accordance with the applicable building code.

**Exception:** Substitute components and connections into approved seismic-force resisting systems shall meet the requirements of Chapter H.

**B3 Design Basis**

The available strength [factored resistance] of the designated seismic force-resisting system shall be greater than or equal to the required strength [effects of factored loads] determined from the applicable load combinations. To ensure the performance of the designated seismic force-resisting system, other structural members and connections in the lateral force-resisting system that are not part of the designated energy-dissipating mechanism shall be designed for the expected strength [probable resistance] of the designated seismic force-resisting system, as specified in Chapter E and Chapter F, including the load effect determined from the applicable load combinations.

**User Note:**

Within the designated lateral force-resisting system, this typically includes the following:

(a) The designated energy-dissipating mechanism is designed and detailed to dissipate energy;
(b) All other structural members and connections permit the necessary energy dissipation to be achieved;
(c) Structural integrity is maintained;
(d) Structural members and connections in the horizontal and vertical load paths are designed to resist the seismic loads;
(e) Diaphragms and collector elements are capable of transmitting the loads developed at each level to the vertical seismic force-resisting system; and
(f) These loads are transmitted to the foundation.

In the U.S. and Mexico, per Section F2.3, the diaphragm chords and diaphragms are required to be designed for the loads from the applicable building code (without consideration of expected strength) and the collectors are required to be designed for the expected strength of the seismic force-resisting system but need not exceed the seismic load effect, including overstrength.

**B3.1 Nominal Strength [Resistance]**

The nominal strength [resistance], \( R_n \), of the seismic force-resisting system shall be determined in accordance with this Standard. The nominal strength [resistance] of all other structural members and connections shall be determined in accordance with the applicable building code.

**B3.2 Available Strength [Factored Resistance]**

The available strength [factored resistance] is stipulated as \( \phi R_n \) for design in accordance with the provisions for load and resistance factor design [limit states design] and \( R_n/\Omega \) for design in accordance with the provisions for allowable strength design (ASD) as designated in Chapter E and Chapter F.

**B3.3 Expected Strength [Probable Resistance]**

For the seismic force-resisting system, the expected strength [probable resistance] shall be determined in accordance with Chapter E.
User Note:
The concept of expected strength [probable resistance] only applies to the seismic force-resisting system; i.e., the system that is being utilized to dissipate energy. All other components in the lateral force-resisting system that are not part of the seismic force-resisting system do not utilize their expected strength [probable resistance].

B3.4 Required Strength [Effects of Factored Loads]

For the seismic force-resisting system, the required strength [effects of factored loads] shall be determined in accordance with the applicable building code.

In the U.S. and Mexico, for all structural members and connections in the lateral force-resisting system that are not part of the designated energy-dissipating mechanism, the required strength shall be determined from the expected strength of the seismic force-resisting system, but need not exceed the seismic load effect including overstrength as designated in Chapter E and Chapter F.

In Canada, for all structural members and connections in the lateral force-resisting system, that are not part of the designated energy-dissipating mechanism, the effect of factored loads shall be determined from the probable resistance of the seismic force-resisting system, but need not exceed the maximum anticipated seismic load effect determined with $R_dR_o=1.0$ as designated in Chapter E and Chapter F.

User Note:
Structural members and connections in the lateral force-resisting system that are not part of the designated energy-dissipating mechanism, as defined for each system in Chapter E, must be designed for force levels that ensure the necessary energy dissipation occurs in the designated mechanism. In the U.S. and Mexico, this is achieved by designing these components for the expected force that the designated mechanism delivers into the components, or more empirically by amplifying the seismic load effects to a sufficiently high level using $\Omega_o$. In Canada, this is achieved by designing these other structural members and connections for the probable force, which is equivalent to probable resistance of the designated mechanism, but not to force levels higher than those determined from an elastic analysis.
C. ANALYSIS

C1 Seismic Load Effects

An analysis conforming to the requirements of the applicable building code and AISI S100 [CSA S136] shall be performed to determine the effect of seismic load combinations on the system, except as modified herein.

D. GENERAL MEMBER AND CONNECTION DESIGN REQUIREMENTS

Design of structural members and connections shall be in accordance with the requirements of Chapters E and F, as appropriate.


E. SEISMIC FORCE-RESISTING SYSTEMS

E1 Cold-Formed Steel Light Frame Shear Walls Sheathed With Wood Structural Panels

E1.1 Scope

Cold-formed steel light frame shear walls sheathed with wood structural panels rated for shear resistance shall be designed in accordance with the requirements of this section.

E1.2 Basis of Design

Cold-formed steel light frame shear walls sheathed with wood structural panels are expected to withstand seismic demands primarily through deformation in the connection between the wood structural panel sheathing and the cold-formed steel structural members.

E1.2.1 Designated Energy-Dissipating Mechanism

The structural member-to-sheathing connection and the wood structural panel sheathing itself are the designated energy-dissipating mechanism in this system.

E1.2.2 Seismic Design Parameters [Seismic Force Modification Factors and Limitations] for Seismic Force-Resisting System

In the U.S. and Mexico, the seismic response modification coefficient, R, shall be determined in accordance with the applicable building code. For cold-formed steel light frame shear walls sheathed with wood structural panels rated for shear resistance, the design shall comply with this section.

User Note:
In the U.S. and Mexico, the seismic response modification coefficient, R, is generally determined from ASCE 7, Table 12.2-1. The systems specified here are listed as an R=6.5 for bearing wall systems in Table 12.2-1, Line A.16, and R=7.0 for building frame systems in Line B.23. To develop the energy dissipation consistent with these seismic response modification coefficients, the requirements specified in this section must be followed.

In Canada, the seismic force modification factors, R_dR_o, shall be determined in accordance with the applicable building code. For cold-formed steel light frame shear walls with wood-based structural panel sheathing, the design shall comply with this section.

User Note:
In Canada, the seismic force modification factors, R_dR_o, are generally determined from the NBCC. The system specified here is listed as R_dR_o=4.25 for screw connected shear walls with wood-based structural panel sheathing. To develop the energy dissipation consistent with these factors, the requirements specified in this section must be followed.

E1.2.3 Type I or Type II Shear Walls

The design of shear walls that resist seismic loads shall be classified as either Type I shear walls or Type II shear walls in accordance with this section.

Type I shear walls shall be full-height sheathed with hold-downs and anchorage at each end. Type I shear walls are permitted to have openings where details are provided to
account for force transfer around openings. Additional requirements are provided in Section E1.3.1.1 and Section E1.4.1.

*Type II shear walls* are permitted to have openings without specific details to account for force transfer around openings. *Hold-downs* and anchorage at each end of the *Type II shear walls* shall be required. Additional requirements provided in Section E1.3.1.2 and Section E1.4.2 shall be met.

## E1.2.4 Seismic Load Effects Contributed by Masonry and Concrete Walls

*Cold-formed steel* light frame *shear walls* sheathed with *wood structural panels* are permitted to be used to provide resistance to seismic forces in buildings or *other structures* with masonry or concrete walls, provided the following requirements are met:

(a) The building or *other structure* is 2 stories or less in height.
(b) The story-to-story wall heights do not exceed 12 ft (3.66 m).
(c) *Diaphragms* are considered flexible and do not cantilever beyond the outermost supporting *shear wall*.
(d) Combined deflections of *diaphragms* and *shear walls* do not permit the *design story drift* of supported masonry or concrete walls to exceed 0.7% of the story height at LRFD design [LSD factored] load levels.
(e) *Wood structural panel* sheathing for both stories of *shear walls* have all unsupported edges blocked and, for the lower story, have a minimum thickness of 15/32” (12 mm).
(f) There are no horizontal out-of-plane offset irregularities as specified by the *applicable building code*.

## E1.3 Shear Strength [Resistance]

### E1.3.1 Nominal Strength [Resistance]

#### E1.3.1.1 Type I Shear Walls

For a *Type I shear wall* sheathed with *wood structural panels*, the *nominal strength* [resistance] for shear, $V_{\text{n}}$, shall be determined in accordance with the following:

For $h/w \leq 2$,

$$V_{\text{n}} = v_{\text{n}}w$$  \hspace{1cm} (Eq. 1.3.1.1-1)

where

- $h$ = Height of the *shear wall*, ft (m)
- $w$ = Length of the *shear wall*, ft (m)
- $v_{\text{n}}$ = *Nominal shear strength* [resistance] per unit length for assemblies with *wood structural panel* and *panel blocking* as specified in Table E1.3-1 as lb/ft (kN/m)

Where permitted in Table E1.3-1, the *nominal strength* [resistance] for shear, $V_{\text{n}}$, 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 $2 < h/w \leq 4$,

$$V_{\text{n}} = v_{\text{n}}w(2w/h)$$  \hspace{1cm} (Eq. 1.3.1.1-2)

In no case shall the height-to-length aspect ratio ($h:w$) exceed 4:1.

The length of a *Type I shear wall* shall not be less than 24 in. (610 mm).
In the U.S. and Mexico, increases in the nominal strengths [resistances] in Table E1.3-1, as allowed by other standards, shall not be permitted.

**E1.3.1.1.1 Wall Pier Limitations**

The height-to-length aspect ratio \((h_p:w_p)\) of a wall pier in a Type I shear wall with openings shall be limited to a maximum of 2:1.

The length of a wall pier \((w_p)\) shall not be less than 24 in. (610 mm).

**E1.3.1.1.2 Both Wall Faces Sheathed With the Same Material and Fastener Spacing**

For a Type I shear wall sheathed with wood structural panels having the same material and fastener spacing on opposite faces of the same wall, the nominal strength [resistance], based on Table E1.3-1, shall be determined by adding the strength from the two opposite faces together.

**E1.3.1.1.3 More Than a Single Sheathing Material or Fastener Configuration**

For a Type I shear wall sheathed with wood structural panels having more than a single sheathing material or fastener spacing, the nominal strength [resistance], based on Table E1.3-1, of the complete wall 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 this section.

For a Type I shear wall sheathed with wood structural panels 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.

For a Type I shear wall sheathed with wood structural panels 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.

**User Note:**

For walls with multiple layers of sheathing on an individual face of a wall, insufficient research exists to provide a definitive solution. Accounting for only the innermost layer when determining the nominal strength [resistance] of the panel is assumed to be conservative, but has not been verified by testing.
Table E1.3-1
Nominal Shear Strength (Resistance) \( (v_n) \) per Unit Length for Seismic and Other In-Plane Loads \(^{1,4} \)
For Shear Walls Sheathed With Wood Structural Panels on One Side of Wall

<table>
<thead>
<tr>
<th>Assembly Description</th>
<th>Max. Aspect Ratio (h:w)</th>
<th>Fastener Spacing at Panel Edges (^2) (in.)</th>
<th>Designation Thickness(^5) of Stud and Track (mils)</th>
<th>Minimum Sheathing Screw Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>15/32&quot; Structural 1 Sheathing (4-ply)</td>
<td>2:1(^3)</td>
<td>890</td>
<td>1330</td>
<td>1775</td>
</tr>
<tr>
<td></td>
<td>2:1(^3)</td>
<td>43 or 54</td>
<td>68</td>
<td>10</td>
</tr>
<tr>
<td>7/16” OSB</td>
<td>2:1(^3)</td>
<td>940</td>
<td>1410</td>
<td>1760</td>
</tr>
<tr>
<td></td>
<td>2:1(^3)</td>
<td>1230</td>
<td>1850</td>
<td>2310</td>
</tr>
</tbody>
</table>

| Canada (kN/m)                             |                         | 150   | 100   | 75    |                           |                           |
|                                           | Max. Aspect Ratio (h:w) | Fastener Spacing at Panel Edges \(^2\) (mm) | Designation Thickness\(^5\) of Stud and Track (mils) | Required Sheathing Screw Size |
|                                           |                         | 150   | 100   | 75    |                           |                           |
| 9.5 mm CSP Sheathing                      | 2:1\(^3\)              | 8.5   | 11.8  | 14.2  | 43 (min.)                 | 8                           |
| 12.5 mm CSP Sheathing                     | 2:1\(^3\)              | 9.5   | 13.0  | 19.4  | 43 (min.)                 | 8                           |
| 12.5 mm DFP Sheathing                     | 2:1\(^3\)              | 11.6  | 17.2  | 22.1  | 43 (min.)                 | 8                           |
| 9 mm OSB 2R24/W24                         | 2:1\(^3\)              | 9.6   | 14.3  | 18.2  | 43 (min.)                 | 8                           |
| 11 mm OSB 1R24/2F16/W24                   | 2:1\(^3\)              | 9.9   | 14.6  | 18.5  | 43 (min.)                 | 8                           |

1. For SI: 1" = 25.4 mm, 1 ft = 0.305 m, 1 lb = 4.45 N. For U.S. Customary Units: 1 mm = 0.0394", 1 m = 3.28 ft, 1 N = 0.225 lb
2. See Section E1.4.1.1 for installation requirements for screws in the field of the panel.
3. See Section E1.3.1.1 for shear wall height-to-length aspect ratios (h:w) greater than 2:1, but not exceeding 4:1.
4. See Section E1.3.1.1.2 and Section E1.3.1.1.3 for requirements for sheathing applied to both sides of wall.
5. Only where Designation Thickness is specified as a (min) is substitution with a thicker member permitted.
**E1.3.1.2 Type II Shear Walls**

For a *Type II shear wall*, the *nominal strength [resistance]* for shear, $V_n$, shall be determined in accordance with the following:

$$V_n = C_a v_n \Sigma L_i$$  \hspace{1cm} (Eq. 1.3.1.2-1)

where

- $C_a$ = Shear resistance adjustment factor from Table E1.3.1.2-1
  
  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.

- $v_n$ = *Nominal shear strength [resistance]* per unit length as specified in Table E1.3-1, lb/ft (kN/m)

- $\Sigma L_i$ = Sum of lengths of *Type II shear wall segments*, ft (m)

<table>
<thead>
<tr>
<th>Table E1.3.1.2-1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shear Resistance Adjustment Factor</strong>- $C_a$</td>
</tr>
<tr>
<td>Maximum Opening Height Ratio $^1$</td>
</tr>
<tr>
<td>1/3</td>
</tr>
<tr>
<td>Percent Full-Height Sheathing $^2$</td>
</tr>
<tr>
<td>10%</td>
</tr>
<tr>
<td>20%</td>
</tr>
<tr>
<td>30%</td>
</tr>
<tr>
<td>40%</td>
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<td>50%</td>
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<td>60%</td>
</tr>
<tr>
<td>70%</td>
</tr>
<tr>
<td>80%</td>
</tr>
<tr>
<td>90%</td>
</tr>
</tbody>
</table>

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1. See Section E1.3.1.2.2.
2. See Section E1.3.1.2.1.

**E1.3.1.2.1 Percent Full-Height Sheathing**

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

**E1.3.1.2.2 Maximum Opening Height Ratio**

The maximum opening height ratio shall be calculated by dividing the maximum opening clear height by the *shear wall* height, $h$.

**E1.3.2 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* and *resistance factors* given in this section in accordance with the applicable design method—ASD, LRFD, or LSD as follows:
\[ \Omega_v = 2.50 \quad (ASD) \]
\[ \phi_v = 0.60 \quad (LRFD) \]
\[ = 0.70 \quad (LSD) \]

**E1.3.3 Expected Strength [Probable Resistance]**

The expected strength [probable resistance] \( \Omega_E V_n \) shall be determined from the nominal strength [resistance] in accordance with this section.

In the U.S. and Mexico, the expected strength factor, \( \Omega_E \), shall be 1.8 for shear walls sheathed with wood structural panels.

In Canada, the expected strength factor, \( \Omega_E \), shall be 1.33 for walls with DFP wood-based structural panel sheathing or OSB wood-based structural panel sheathing, and 1.45 for walls with CSP wood-based structural panel sheathing.

**E1.4 System Requirements**

**E1.4.1 Type I Shear Walls**

**E1.4.1.1 Limitations for Tabulated Systems**

The Type I shear wall seismic force-resisting system specified in Table E1.3-1 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) Chord studs, or other vertical boundary elements at the ends of wall segments braced with sheathing, are anchored such that the bottom track is not required to resist uplift by bending of the track web.

(e) Screws for structural members are a minimum No. 8 and comply with ASTM C1513.

(f) Fasteners along the edges in shear panels are placed from panel edges not less than the following, as applicable:

(1) In the U.S. and Mexico, 3/8 in. (9.5 mm).

(2) In Canada, 12.5 mm (1/2 in.).

(g) Fasteners in the field of the panel are installed 12 in. (305 mm) o.c. unless otherwise specified.

(h) Panel thicknesses are taken as minimums.

(i) Panels less than 12 in. (305 mm) wide are not permitted.

(j) Maximum stud spacing is 24 in. (610 mm) on center.

(k) All sheathing edges are attached to structural members or panel blocking.

(l) Where used as panel blocking, flat strap is a minimum thickness of 33 mils with a
minimum width of 1-1/2 in. (38.1 mm) and is installed below the sheathing.

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

(n) Wood structural panel sheathing is manufactured using exterior glue and complies with the following, as applicable:

1. In the U.S. and Mexico, DOC PS 1 or DOC PS 2.
2. In Canada, CSA-O121, CSA-O151 or CSA-O325.

(o) Wood structural panel sheathing is permitted to be applied either parallel to or perpendicular to studs.

(p) Wood structural panel sheathing is attached to cold-formed steel structural members with either No. 8 self-tapping screws with a minimum head diameter of 0.285 in. (7.24 mm) or No. 10 self-tapping screws with a minimum head diameter of 0.333 in. (8.46 mm).

(q) Screws used to attach wood structural panel sheathing to cold-formed steel structural members comply with ASTM C1513.

(r) The pull-out resistance of screws is not used to resist seismic forces.

E1.4.1.2 Required Strength [Effect of Factored Loads] for Chord Studs, Anchorage, and Collectors

In the U.S. and Mexico, for collectors, chord studs, other vertical boundary elements, hold-downs and anchorage connected thereto, and all other components and connections of the shear wall that are not part of the designated energy-dissipating mechanism, the required strength shall be determined from the expected strength of the shear wall, but need not exceed the load effect determined from applicable load combinations including seismic load with overstrength. The available strength of the collectors, chord studs, other vertical boundary members, hold-downs and anchorage connected thereto, and all other components and connections of the shear wall shall be greater than or equal to the required strength.

In Canada, for collectors, chord studs, other vertical boundary elements, hold-downs and anchorage connected thereto, and all other components and connections of the lateral force-resisting system that are not part of the designated energy-dissipating mechanism, the effect of factored loads shall be determined from the probable resistance of the seismic force-resisting system, but need not exceed the maximum anticipated seismic load effect determined with $R_dR_o=1.0$. The factored resistance of the chord studs, other vertical boundary elements, hold-downs and anchorage connected thereto, and all other components and connections in the lateral force-resisting system shall be greater than or equal to the effects of factored loads determined from the applicable load combinations.

E1.4.1.3 Required Strength [Effect of Factored Loads] for Foundations

In the U.S. and Mexico, for foundations, the required strength shall be determined from the seismic load effect and need not include the overstrength factor ($\Omega_o$) nor consider the expected strength of the seismic force-resisting system unless otherwise specified in the applicable building code.

In Canada, for foundations in Type I shear walls, the effect of factored loads shall be determined from the probable resistance of the seismic force-resisting system, but need not...
exceed the maximum anticipated seismic load effect determined with $R_dR_o=1.0$.

**E1.4.1.4 Design Deflection**

The deflection of a blocked cold-formed steel light frame shear wall sheathed with wood structural panels is permitted to be calculated in accordance with the following:

$$\delta = \frac{2vh^3}{3EA_c b} + \frac{v+h}{\rho Gt_{sheathing}} + \frac{v+5/4}{\omega_2 \omega_3 \omega_4} \left(\frac{v}{b}\right)^2 + \frac{h}{b} \delta_v \quad (Eq. E1.4.1.4-1)$$

where

- $A_c$ = Gross cross-sectional area of chord member, in square in. (mm²)
- $b$ = Length of the shear wall, in. (mm)
- $E$ = Modulus of elasticity of steel = 29,500,000 psi (203,000 MPa)
- $G$ = Shear modulus of sheathing material, in lb/ in.² (MPa)
- $h$ = Wall height, in. (mm)
- $s$ = Maximum fastener spacing at panel edges, in. (mm)
- $t_{sheathing}$ = Nominal panel thickness, in. (mm)
- $t_{stud}$ = Stud designation thickness, in. (mm)
- $v$ = Shear demand, in lb/ in. (N/mm)
- $V$ = Total lateral load applied to the shear wall, in lb (N)
- $\beta$ = 67.5 for plywood other than Canadian Softwood Plywood (CSP)
  = 55 for OSB and CSP for U.S. Customary Units (lb/in.¹⁵)
  = 2.35 for plywood other than CSP
  = 1.91 for OSB and CSP for SI units (N/mm¹⁵)
- $\delta$ = Calculated deflection, in. (mm)
- $\delta_v$ = Vertical deformation of anchorage/attachment details, in. (mm)
- $\rho$ = 1.85 for plywood other than CSP, 1.05 for OSB and CSP
- $\omega_1$ = $s/6$ (for $s$ in in.) and $s/152.4$ (for $s$ in mm) \quad (Eq. E1.4.1.4-3)
- $\omega_2$ = $0.033/t_{stud}$ (for $t_{stud}$ in in.) \quad (Eq. E1.4.1.4-4a)
  = $0.838/t_{stud}$ (for $t_{stud}$ in mm) \quad (Eq. E1.4.1.4-4b)
- $\omega_3 = \sqrt{\frac{(h/b)}{2}} \quad (Eq. E1.4.1.4-5)$
- $\omega_4 = 1$ for wood structural panel sheathing

**E1.4.2 Type II Shear Walls**

Type II shear walls shall meet all of the requirements for Type I shear walls except where amended by the applicable requirements of Section E1.2.3 and this section.

**E1.4.2.1 Additional Limitations**

The Type II shear wall seismic force-resisting system shall conform to the following...
requirements:
(a) A Type II shear wall segment, meeting the aspect ratio (h:w) limitations of Section E1.3.1, is located at each end of a Type II shear wall. Openings are permitted to occur beyond the ends of the Type II shear wall; however, the length of such openings is not included in the length of the Type II shear wall.
(b) The nominal strength [resistance] for shear, V_n, is based upon a screw spacing of not less than 4 in. (100 mm) o.c.
(c) Where horizontal out-of-plane offset irregularities occur, portions of the wall on each side of the offset 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) A Type II shear wall has uniform top-of-wall and bottom-of-wall elevations.
(f) Type II shear wall height, h, does not exceed 20 ft (6.1 m).

User Note:
Type II shear walls not having uniform elevations need to be designed by other methods.

E1.4.2.2 Required Strength [Effect of Factored Loads] for Chord Studs, Anchorage, and Collectors

Design of collectors connecting Type II shear wall segments and anchorage at the ends or between Type II shear wall segments shall conform to the requirements of this section.

E1.4.2.2.1 Collectors Connecting In-Plane Type II Shear Wall Segments

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

\[ v = \frac{V}{C_a \sum L_i} \]  

(Eq. E1.4.2.2-1)

where

- \( v \) = Shear force per unit length (plf, kN/m)
- \( V \) = Shear force in Type II shear wall (lb, kN)

In the U.S. and Mexico, V is based on the expected strength of the Type II shear wall segment, but need not exceed the seismic load effect including overstrength.

User Note:
For shear walls sheathed with wood structural panels, the expected strength is set as the seismic load effect including overstrength as per E1.3.3.

In Canada, V is based on the probable resistance of the Type II shear wall segment, but need not exceed the seismic load effect determined with \( R_d R_o = 1.0 \).

- \( C_a \) = Shear resistance adjustment factor from Table E1.3.1.2-1
- \( \sum L_i \) = Sum of lengths of Type II shear wall segments (ft, m)

E1.4.2.2.2 Uplift Anchorage and Boundary Chord Forces at Type II Shear Wall Ends

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

\[
C = \frac{Vh}{C_a \sum L_i}
\]

where

- \( C \) = Boundary chord force (tension/compression) (lb, kN)
- \( V \) = Shear force in Type II shear wall (lb, kN)

In the U.S. and Mexico, \( V \) is based on the expected strength of the Type II shear wall segment, but need not exceed the seismic load effect including overstrength.

In Canada, \( V \) is based on the probable resistance of the Type II shear wall segment, but need not exceed the seismic load effect determined with \( R_d R_o = 1.0 \).

- \( h \) = Shear wall height (ft, m)
- \( C_a \) = Shear resistance adjustment factor from Table E1.3.1.2-1
- \( \sum L_i \) = Sum of lengths of Type II shear wall segments (ft, m)

**User Note:**
Uplift can be reduced by the dead load and chord forces can be increased by dead load.

**E1.4.2.2.3 Uplift Anchorage Between Type II Shear Wall Ends**

In addition to the requirements of Section E1.4.2.2.2, 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 E1.4.2.2.1.

**E1.4.2.3 Design Deflection**

The deflection of a Type II shear wall shall be determined by principles of mechanics considering the deformation of the sheathing and its attachment, chord studs, hold-downs and anchorage.

**E2 Cold-Formed Steel Light Frame Shear Walls With Steel Sheet Sheathing**

**E2.1 Scope**

Cold-formed steel light frame shear walls with steel sheet sheathing shall be designed in accordance with the requirements of this section.

**E2.2 Basis of Design**

Cold-formed steel light frame shear walls with steel sheet sheathing are expected to withstand seismic demands primarily through deformation in the connection between the steel sheet sheathing and cold-formed steel structural members.

**E2.2.1 Designated Energy-Dissipating Mechanism**

The structural member-to-sheathing connection and the steel sheet sheathing itself are the designated energy-dissipating mechanism in this system.
E2.2.2 Seismic Design Parameters [Seismic Force Modification Factors and Limitations] for Seismic Force-Resisting System

In the U.S. and Mexico, the seismic response modification coefficient, \( R \), shall be determined in accordance with the applicable building code. For cold-formed steel light frame shear walls with steel sheet sheathing, the design shall comply with this section.

User Note:
In the U.S. and Mexico, the seismic response modification coefficient, \( R \), is generally determined from ASCE 7, Table 12.2-1. The systems specified here are listed as an \( R=6.5 \) for bearing wall systems in Table 12.2-1, Line A.16, and \( R=7.0 \) for building frame systems in Line B.23. To develop the energy dissipation consistent with these seismic response modification coefficients, the requirements specified in this section must be followed.

In Canada, the seismic force modification factors, \( R_dR_o \), shall be determined in accordance with Appendix 1. For cold-formed steel light frame shear walls with steel sheet sheathing, the design shall comply with this section.

User Note:
In Canada, the seismic force modification factors, \( R_dR_o \), are generally determined from the NBCC. However, since this is a relatively new system for Canada, the seismic force modification factors, \( R_dR_o \), and limitations have not yet been adopted by the NBCC. The system specified here is listed as \( R_dR_o=2.6 \) for screw-connected shear walls with steel sheet sheathing. To develop the energy dissipation consistent with these factors, the requirements specified in this section must be followed.

E2.2.3 Type I or Type II Shear Walls

The design of shear walls that resist seismic loads shall be classified as either Type I shear walls or Type II shear walls in accordance with this section.

Type I shear walls shall be full-height sheathed with hold-downs and anchorage at each end. Type I shear walls are permitted to have openings where details are provided to account for force transfer around openings. Additional requirements are provided in Section E2.3.1.1 and Section E2.4.1.

Type II shear walls are permitted to have openings without specific details to account for force transfer around openings. Hold-downs and anchorage at each end of the Type II shear walls shall be required. Additional requirements provided in Section E2.3.1.2 and Section E2.4.2 shall be met.

E2.2.4 Seismic Load Effects Contributed by Masonry and Concrete Walls

Cold-formed steel light frame shear walls with steel sheet sheathing are permitted to be used to provide resistance to seismic forces in buildings and other structures with masonry or concrete walls, provided the following requirements are met:
(a) The building or other structure is 2 stories or less in height.
(b) The story-to-story wall heights do not exceed 12 ft (3.66 m).
(c) Diaphragms are considered flexible and do not cantilever beyond the outermost supporting shear wall.
(d) Combined deflections of diaphragms and shear walls do not permit per story drift of
supported masonry or concrete walls to exceed 0.7% of the story height at LRFD design [LSD factored] load levels.

(e) Steel sheet sheathing for both stories of shear walls have all unsupported edges blocked and, for the lower story, have a minimum thickness of 0.027” (0.683 mm).

(f) There are no horizontal out-of-plane offset irregularities as specified by the applicable building code.

E2.3 Shear Strength [Resistance]

E2.3.1 Nominal Strength [Resistance]

E2.3.1.1 Type I Shear Walls

For a Type I shear wall with steel sheet sheathing, the nominal strength [resistance] for shear, \( V_n \), shall be determined in accordance with the following:

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

\[
V_n = v_n w \quad \text{(Eq. E2.3.1.1-1)}
\]

where

- \( h \) = Height of the shear wall, ft (m)
- \( w \) = Length of the shear wall, ft (m)
- \( v_n \) = Nominal shear strength [resistance] per unit length for assemblies with steel sheet sheathing and panel blocking as specified in Table E2.3-1 lb/ft (kN/m) or determined in accordance with Section E2.3.1.1.1

Where permitted in Table E2.3-1 or Section E2.3.1.1.1, the nominal strength [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 \( 2 < h/w \leq 4 \),

\[
V_n = v_n w (2w/h) \quad \text{(Eq. E2.3.1.1-2)}
\]

In no case shall the height-to-length aspect ratio (\( h/w \)) exceed 4:1.

The length of a Type I shear wall shall not be less than 24 in. (610 mm).

E2.3.1.1.1 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 a Type I shear wall with steel sheet sheathing, which meets the limitations specified in Section E2.3.1.1.1, is permitted to be determined in accordance with the effective strip method as follows:

\[
V_n = \text{minimum} (1.33P_n \cos \alpha, 1.33w_e t F_y \cos \alpha) \quad \text{(Eq. E2.3.1.1.1-1)}
\]

where

- \( P_n \) = Nominal shear strength [resistance] of screw connections within the effective strip width, \( W_e \), on the steel sheet sheathing
- \( \alpha \) = \( \text{Arctan}(h/w) \) \quad \text{(Eq. E2.3.1.1.1-2)}
- \( h \) = Shear wall height
- \( w \) = Shear wall length
- \( t \) = Design thickness of steel sheet sheathing
F_y = Yield stress of steel sheet sheathing

w_e = w_{max}, \text{ when } \lambda \leq 0.0819 \quad (Eq. E2.3.1.1.1-3)

= \rho w_{max}, \text{ when } \lambda > 0.0819 \quad (Eq. E2.3.1.1.1-4)

where

\lambda = \frac{-0.55(\lambda - 0.08)^{0.12}}{\rho^{0.12}} \quad (Eq. E2.3.1.1.1-5)

\rho = \frac{1 - \alpha_1 \alpha_2}{\beta_1 \beta_2 \beta_3 a} \quad (Eq. E2.3.1.1.1-7)

where

\alpha_1 = \frac{F_{ush}}{45} \quad (For \ F_{ush} \text{ in ksi}) \quad (Eq. E2.3.1.1.1-8)

= \frac{F_{ush}}{310.3} \quad (For \ F_{ush} \text{ in MPa}) \quad (Eq. E2.3.1.1.1-9)

\alpha_2 = \frac{F_{uf}}{45} \quad (For \ F_{uf} \text{ in ksi}) \quad (Eq. E2.3.1.1.1-10)

= \frac{F_{uf}}{310.3} \quad (For \ F_{uf} \text{ in MPa}) \quad (Eq. E2.3.1.1.1-11)

\beta_1 = \frac{t_{sh}}{0.018} \quad (For \ t_{sh} \text{ in in.)} \quad (Eq. E2.3.1.1.1-12)

= \frac{t_{sh}}{0.457} \quad (For \ t_{sh} \text{ in mm}) \quad (Eq. E2.3.1.1.1-13)

\beta_2 = \frac{t_f}{0.018} \quad (For \ t_f \text{ in in.)} \quad (Eq. E2.3.1.1.1-14)

= \frac{t_f}{0.457} \quad (For \ t_f \text{ in mm}) \quad (Eq. E2.3.1.1.1-15)

\beta_3 = \frac{s}{6} \quad (For \ s \text{ in in.)} \quad (Eq. E2.3.1.1.1-16)

= \frac{s}{152.4} \quad (For \ s \text{ in mm}) \quad (Eq. E2.3.1.1.1-17)

F_{ush} = Tensile strength of steel sheet sheathing

F_{uf} = Minimum tensile strength of framing materials

T_{sh} = Design thickness of steel sheet sheathing

T_f = Minimum design thicknesses of framing members

s = Screw spacing on the panel edges

a = Wall aspect ratio (h:w)

= \frac{h}{w} \quad (Eq. E2.3.1.1.1-18)

**E2.3.1.1.1** 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-length 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 E2.3.1.1 for Type I shear wall height-to-length aspect ratios (h:w) greater than 2:1, but not exceeding 4:1 for additional requirements.

**E2.3.1.1.2 Wall Pier Limitations**

The height-to-length aspect ratio (h_p:w_p) of a wall pier in a Type I shear wall with
openings shall be limited to a maximum of 2:1.

The length of a wall pier \( (w_p) \) shall not be less than 24 in. (610 mm).

**E2.3.1.1.3 Both Wall Faces Sheathed With the Same Material and Fastener Spacing**

For a Type I shear wall with steel sheet sheathing having the same material and fastener spacing on opposite faces of the same wall, the nominal strength [resistance], based on Table E2.3-1, shall be determined by adding the strength from the two opposite faces together.

**E2.3.1.1.4 More Than a Single Sheathing Material or Fastener Configuration**

For a Type I shear wall with steel sheet sheathing having more than a single sheathing material or fastener spacing, the nominal strength [resistance], based on Table E2.3-1 or Section E2.3.1.1.1, of the complete wall shall not be permitted to be determined by adding the strength from the different individual walls. Rather, it shall be determined in accordance with this section.

For a Type I shear wall with steel sheet sheathing 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.

For a Type I shear wall with steel sheet sheathing 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.

**User Note:**

For walls with multiple layers of sheathing on an individual face of a wall, insufficient research exists to provide a definitive solution. Accounting for only the innermost layer when determining the strength [resistance] of the panel is assumed to be conservative, but has not been verified by testing.
### Table E2.3-1
Nominal Shear Strength [Resistance] \((v_n)\) per Unit Length for Seismic and Other In-Plane Loads \(^{1,4}\)
for Shear Walls With Steel Sheet Sheathing on One Side of Wall

<table>
<thead>
<tr>
<th>Assembly Description</th>
<th>Max. Aspect Ratio ((h:w))</th>
<th>Fastener Spacing at Panel Edges (^{2}) (in.)</th>
<th>Stud Blocking Required</th>
<th>Designation Thickness(^{3}) of Stud, Track and Stud Blocking (mils)</th>
<th>Minimum Sheathing Screw Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>0.018” steel sheet</td>
<td>2:1</td>
<td>390</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.027” steel sheet</td>
<td>2:1(^{3})</td>
<td>-</td>
<td>1000</td>
<td>1085</td>
<td>1170</td>
</tr>
<tr>
<td></td>
<td>2:1(^{3})</td>
<td>647</td>
<td>710</td>
<td>778</td>
<td>845</td>
</tr>
<tr>
<td>0.030” steel sheet</td>
<td>2:1(^{3})</td>
<td>910</td>
<td>1015</td>
<td>1040</td>
<td>1070</td>
</tr>
<tr>
<td></td>
<td>2:1(^{3})</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1355</td>
</tr>
<tr>
<td>0.033” steel sheet</td>
<td>2:1(^{3})</td>
<td>1055</td>
<td>1170</td>
<td>1235</td>
<td>1305</td>
</tr>
<tr>
<td></td>
<td>2:1(^{3})</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1505</td>
</tr>
<tr>
<td></td>
<td>2:1(^{3})</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1870</td>
</tr>
<tr>
<td></td>
<td>2:1(^{3})</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2085</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assembly Description</th>
<th>Max. Aspect Ratio ((h:w))</th>
<th>Fastener Spacing at Panel Edges (^{2}) (mm)</th>
<th>Stud Blocking Required</th>
<th>Designation Thickness(^{3}) of Stud, Track and Stud Blocking (mils)</th>
<th>Required Sheathing Screw Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>150</td>
<td>100</td>
<td>75</td>
<td>50</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>0.68 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</td>
<td>8.9</td>
<td>10.6</td>
<td>11.6</td>
<td>12.5</td>
</tr>
<tr>
<td>0.84 mm steel sheet</td>
<td>4:1</td>
<td>10.7</td>
<td>12.0</td>
<td>13.0</td>
<td>14.0</td>
</tr>
<tr>
<td>0.46 mm steel sheet</td>
<td>4:1</td>
<td>7.4</td>
<td>9.7</td>
<td>11.6</td>
<td>13.5</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>
</tbody>
</table>

1. For SI: 1” = 25.4 mm, 1 ft = 0.305 m, 1 lb = 4.45 N. For U.S. Customary Units: 1 mm = 0.0394”, 1 m = 3.28 ft, 1 N = 0.225 lb
2. See Section E2.4.1.1 for installation requirements for screws in the field of the panel.
3. See Section E2.3.1.1 for shear wall height to length aspect ratios \((h:w)\) greater than 2:1, but not exceeding 4:1.
4. See Section E2.3.1.1.2 and Section E2.3.1.1.3 for requirements for sheathing applied to both sides of wall.
5. Only where Designation Thickness is specified as a (min) is substitution with a thicker member permitted.

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E2.3.1.2 Type II Shear Walls

For a Type II shear wall, the nominal strength [resistance] for shear, \( V_n \), shall be determined in accordance with the following:

\[
V_n = C_a v_n \sum L_i \tag{Eq. 2.3.1.2-1}
\]

where

\( C_a = \) Shear resistance adjustment factor from Table E2.3.1.2-1

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.

\( v_n = \) Nominal shear strength [resistance] per unit length as specified in Table E2.3-1, lb/ft (kN/m)

\( \sum L_i = \) Sum of lengths of Type II shear wall segments, ft (m)

### Table E2.3.1.2-1
Shear Resistance Adjustment Factor-\( C_a \)

<table>
<thead>
<tr>
<th>Percent Full-Height Sheathing</th>
<th>1/3</th>
<th>1/2</th>
<th>2/3</th>
<th>5/6</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>1.00</td>
<td>0.69</td>
<td>0.53</td>
<td>0.43</td>
<td>0.36</td>
</tr>
<tr>
<td>20%</td>
<td>1.00</td>
<td>0.71</td>
<td>0.56</td>
<td>0.45</td>
<td>0.38</td>
</tr>
<tr>
<td>30%</td>
<td>1.00</td>
<td>0.74</td>
<td>0.59</td>
<td>0.49</td>
<td>0.42</td>
</tr>
<tr>
<td>40%</td>
<td>1.00</td>
<td>0.77</td>
<td>0.63</td>
<td>0.53</td>
<td>0.45</td>
</tr>
<tr>
<td>50%</td>
<td>1.00</td>
<td>0.80</td>
<td>0.67</td>
<td>0.57</td>
<td>0.50</td>
</tr>
<tr>
<td>60%</td>
<td>1.00</td>
<td>0.83</td>
<td>0.71</td>
<td>0.63</td>
<td>0.56</td>
</tr>
<tr>
<td>70%</td>
<td>1.00</td>
<td>0.87</td>
<td>0.77</td>
<td>0.69</td>
<td>0.63</td>
</tr>
<tr>
<td>80%</td>
<td>1.00</td>
<td>0.91</td>
<td>0.83</td>
<td>0.77</td>
<td>0.71</td>
</tr>
<tr>
<td>90%</td>
<td>1.00</td>
<td>0.95</td>
<td>0.91</td>
<td>0.87</td>
<td>0.83</td>
</tr>
<tr>
<td>100%</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

1. See Section E2.3.1.2.2.
2. See Section E2.3.1.2.1.

E2.3.1.2.1 Percent Full-Height Sheathing

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.

E2.3.1.2.2 Maximum Opening Height Ratio

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

E2.3.2 Available Strength [Factored Resistance]

The available strength [factored resistance] (\( \phi_v V_n \) for LRFD and LSD or \( V_n/\Omega \) for ASD) shall be determined from the nominal strength [resistance] using the applicable safety factors and resistance factors given in this section in accordance with the applicable design method—ASD, LRFD, or LSD as follows:
\[ \Omega_v = 2.50 \quad (ASD) \]
\[ \phi_v = 0.60 \quad (LRFD) \]
\[ = 0.70 \quad (LSD) \]

**E2.3.3 Expected Strength [Probable Resistance]**

The expected strength [probable resistance] \( (\OmegaEVn) \) shall be determined from the nominal strength [resistance] in accordance with this section.

In the U.S. and Mexico, the expected strength factor, \( \OmegaE \), shall be 1.8 for shear walls with steel sheet sheathing.

In Canada, the expected strength factor, \( \OmegaE \), shall be 1.4 for walls with steel sheet sheathing.

**E2.4 System Requirements**

**E2.4.1 Type I Shear Walls**

**E2.4.1.1 Limitations for Tabulated Systems**

The Type I shear wall seismic force-resisting system specified in Table E2.3-1 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) Chord studs, or other vertical boundary elements at the ends of wall segments braced with sheathing, are anchored such that the bottom track is not required to resist uplift by bending of the track web.

(e) Screws for structural members are a minimum No. 8 and comply with ASTM C1513.

(f) Fasteners along the edges in shear panels are placed from panel edges not less than the following, as applicable:

   (1) In the U.S. and Mexico, 3/8 in. (9.5 mm).

   (2) In Canada, 12.5 mm (1/2 in.).

(g) Fasteners in the field of the panel are installed 12 in. (305 mm) o.c. unless otherwise specified.

(h) Panel thicknesses are taken as minimums.

(i) Panels less than 12-in. (305-mm) wide are not permitted.

(j) Maximum stud spacing is 24 in. (610 mm) on center.

(k) All sheathing edges are attached to structural members or panel blocking.

(l) In lieu of panel blocking, unblocked assemblies with panel edges are permitted to be overlapped and attached to each other with screw spacing as required for panel
edges. Where such a connection is used, the nominal strength [resistance] provided in Table E2.3-1 is to be multiplied by 0.70.

(m) Where used as panel blocking, flat strap is a minimum thickness of 33 mils with a minimum width of 1-1/2 in. (38.1 mm) and is installed either on top of or below the sheathing.

(n) Steel sheet sheathing has a minimum base steel thickness as specified in Table E2.3-1 and complies with ASTM A1003 Structural Grade 33 (Grade 230) Type H.

(o) In Canada, steel sheet sheathing shall be connected without horizontal joints.

(p) Where shear walls require multiple vertical sheathing panels, a single stud shall be used at the sheathing joint, unless the connection between the combined studs is designed for the shear transfer between panels.

(q) Screws used to attach steel sheet sheathing comply with ASTM C1513.

(r) Stud blocking is installed at quarter-points for all shear wall heights and meets either of the following requirements:

1. In-line block-and-strap method: In-line blocking is a stud or track section with the same web depth and minimum thickness as the studs. Flat straps have a minimum thickness of 33 mils with a minimum width of 1-1/2 in. (38.1 mm). In-line blocking is installed between studs at the termination of all flat straps, at 12 ft (3.66 m) intervals along the flat strap, and at the ends of the shear wall. Flat straps are attached to the flanges of each stud with a minimum of one No. 8 screw and to the flanges of the in-line blocking with a minimum of two No. 8 screws. In-line blocking is attached to each stud with a minimum of one No. 8 screw.

2. Solid-block method: In-line blocking is a stud or track section with the same web depth and minimum thickness as the studs. In-line blocking is installed between every stud. In-line blocking is attached to each stud with a minimum of one No. 8 screw.

(s) The pull-out resistance of screws is not used to resist seismic forces.

E2.4.1.2 Required Strength [Effect of Factored Loads] for Chord Studs, Anchorage, and Collectors

In the U.S. and Mexico, for collectors, chord studs, other vertical boundary elements, hold-downs and anchorage connected thereto, and all other components and connections of the shear wall that are not part of the designated energy-dissipating mechanism, the required strength shall be determined from the expected strength of the shear wall, but need not exceed the load effect determined from applicable load combinations including seismic loads with overstrength. The available strength of the collectors, chord studs, other vertical boundary elements, hold-downs and anchorage connected thereto, and all other components and connections of the shear wall shall be greater than or equal to the required strength.

In Canada, for collectors, chord studs, other vertical boundary elements, hold-downs and uplift anchorage connected thereto, and all other components and connections in the lateral force-resisting system that are not part of the designated energy-dissipating mechanism, the effect of factored loads shall be determined from the probable resistance of the seismic force-resisting system, but need not exceed the maximum anticipated seismic load effect determined with $R_d R_o = 1.0$. The factored resistance of the collectors, chord studs, other vertical boundary elements, hold-downs and anchorage connected thereto, collectors, and all

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other components and connections of the lateral force-resisting system shall be greater than or equal to the effects of factored loads determined from the applicable load combinations.

E2.4.1.3 Required Strength [Effect of Factored Loads] for Foundations

In the U.S. and Mexico, for foundations, the required strength shall be determined from the seismic load effect and need not include the overstrength factor \((\Omega_o)\) nor consider the expected strength of the seismic force-resisting system unless otherwise specified in the applicable building code.

In Canada, for foundations in Type I shear walls, the effect of factored loads shall be determined from the probable resistance of the seismic force-resisting system, but need not exceed the maximum anticipated seismic load effect determined with \(R_dR_o=1.0\).

E2.4.1.4 Design Deflection

The deflection of a blocked cold-formed steel light frame Type I shear wall with steel sheet sheathing is permitted to be calculated in accordance with the following:

\[
\delta = \frac{2vh^3}{3EA_c b} + \frac{vh}{\rho G t_{\text{sheathing}}} + \frac{v_1}{2}\left\{\frac{v}{\beta}\right\}^2 + \frac{h}{b}\delta_v \quad (Eq. E2.4.1.4-1)
\]

where
- \(A_c\) = Gross cross-sectional area of chord member, in square in. (mm²)
- \(b\) = Length of the shear wall, in in. (mm)
- \(E\) = Modulus of elasticity of steel
  - \(= 29,500,000\) psi \((203,000\) MPa)
- \(G\) = Shear modulus of sheathing material, in lb/ in² (MPa)
- \(h\) = Wall height, in in. (mm)
- \(s\) = Maximum fastener spacing at panel edges, in in. (mm)
- \(t_{\text{sheathing}}\) = Nominal panel thickness, in in. (mm)
- \(t_{\text{stud}}\) = Stud designation thickness, in in. (mm)
- \(v\) = Shear demand, in lb/ in. (N/mm)
  - \(= V/b\) \((Eq. E2.4.1.4-2)\)
- \(V\) = Total lateral load applied to the shear wall, in lb (N)
- \(\beta\) = \(29.12 \times \left(t_{\text{sheathing}}/0.018\right)\) for steel sheet (for \(t_{\text{sheathing}}\) in in.) \((lb/in^{1.5})\)
  - \(= 1.01 \times \left(t_{\text{sheathing}}/0.457\right)\) for steel sheet (for \(t_{\text{sheathing}}\) in mm) \((N/mm^{1.5})\) \((Eq. E2.4.1.4-3a)\)
- \(\delta\) = Calculated deflection, in in. (mm)
- \(\delta_v\) = Vertical deformation of anchorage/attachment details, in in. (mm)
- \(\rho\) = \(0.075 \times \left(t_{\text{sheathing}}/0.018\right)\) for steel sheet (for \(t_{\text{sheathing}}\) in in.)
  - \(= 0.075 \times \left(t_{\text{sheathing}}/0.457\right)\) for steel sheet (for \(t_{\text{sheathing}}\) in mm) \((Eq. E2.4.1.4-4a)\)
- \(\omega_1\) = \(s/6\) (for \(s\) in in.) and \(s/152.4\) (for \(s\) in mm) \((Eq. E2.4.1.4-5)\)
\[ \omega_2 = \frac{0.033}{t_{\text{stud}}} \quad \text{(for } t_{\text{stud}} \text{ in in.)} \]  
\[ = \frac{0.838}{t_{\text{stud}}} \quad \text{(for } t_{\text{stud}} \text{ in mm)} \]  
\[ \omega_3 = \sqrt{\frac{(h/b)}{2}} \quad \text{(Eq. E2.4.1.4-7)} \]  
\[ \omega_4 = \sqrt{\frac{33}{F_y}} \quad \text{(for } F_y \text{ in ksi)} \]  
\[ = \sqrt{\frac{227.5}{F_y}} \quad \text{(for } F_y \text{ in MPa) for steel sheet} \]  

**E2.4.2 Type II Shear Walls**

Type II shear walls shall meet all of the requirements for Type I shear walls except where amended by the applicable requirements of Section E2.2.3 and this section.

**E2.4.2.1 Additional Limitations**

The Type II shear wall seismic force-resisting system shall conform to the following requirements:

(a) A Type II shear wall segment, meeting the aspect ratio (h:w) limitations of Section E2.3.1, is located at each end of a Type II shear wall. Openings are permitted to occur beyond the ends of the Type II shear wall; however, the length of such openings is not included in the length of the Type II shear wall.

(b) The nominal strength [resistance] for shear, \( V_n \), is based upon a screw spacing of not less than 4 in. (100 mm) o.c.

(c) Where horizontal out-of-plane offset irregularities occur, portions of the wall on each side of the offset 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) A Type II shear wall has uniform top-of-wall and bottom-of-wall elevations.

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

**User Note:**

Type II shear walls not having uniform elevations need to be designed by other methods.

**E2.4.2.2 Required Strength [Effects of Factored Loads] for Chord Studs, Anchorage, and Collectors**

Design of collectors connecting Type II shear wall segments and anchorage at the ends or between Type II shear wall segments shall conform to the requirements of this section, or shall be determined using principles of mechanics.

**E2.4.2.2.1 Collectors Connecting In-Plane Type II Shear Wall Segments**

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

\[ v = \frac{V}{C_a \sum L_i} \quad \text{(Eq. E2.4.2.2-1)} \]
where

\[ v = \text{Shear force per unit length (plf, kN/m)} \]

\[ V = \text{Shear force in Type II shear wall (lb, kN)} \]

In the U.S. and Mexico, \( V \) is based on the expected strength of the shear wall segment, but need not exceed the seismic load effect including overstrength.

**User Note:**
For shear walls with steel sheet sheathing, the expected strength is set as the seismic load effect including overstrength as per Section E2.3.3.

In Canada, \( V \) is based on the probable resistance of the shear wall segment, but need not exceed the seismic load effect determined with \( R_dR_o=1.0 \).

\[ C_a = \text{Shear resistance adjustment factor from Table E2.3.1.2-1} \]

\[ \Sigma L_i = \text{Sum of lengths of Type II shear wall segments (ft, m)} \]

**E2.4.2.2.2 Uplift Anchorage and Boundary Chord Forces at Type II Shear Wall Ends**

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

\[
C = \frac{Vh}{C_a \Sigma L_i}
\]

(Eq. E2.4.2.2-2)

where

\[ C = \text{Boundary chord force (tension/compression) (lb, kN)} \]

\[ V = \text{Shear force in Type II shear wall (lb, kN)} \]

In the U.S. and Mexico, \( V \) is based on the expected strength of the shear wall segment, but need not exceed the seismic load effect including overstrength.

In Canada, \( V \) is based on the probable resistance of the shear wall segment, but need not exceed the seismic load effect determined with \( R_dR_o=1.0 \).

\[ h = \text{Shear wall height (ft, m)} \]

\[ C_a = \text{Shear resistance adjustment factor from Table E2.3.1.2-1} \]

\[ \Sigma L_i = \text{Sum of lengths of Type II shear wall segments (ft, m)} \]

**User Note:**
Uplift can be reduced by the dead load and chord forces can be increased by dead load.

**E2.4.2.2.3 Uplift Anchorage Between Type II Shear Wall Ends**

In addition to the requirements of Section E2.4.2.2.2, 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 E2.4.2.2.1.

**E2.4.2.3 Design Deflection**

The deflection of a Type II shear wall shall be determined by principles of mechanics considering the deformation of the sheathing and its attachment, chord studs, hold-downs and anchorage.
E3 Cold-Formed Steel Light Frame Strap Braced Wall Systems

E3.1 Scope

Cold-formed steel light frame strap braced wall systems shall be designed in accordance with the requirements of this section.

E3.2 Basis of Design

Cold-formed steel light frame strap braced wall systems are expected to withstand seismic demands primarily through tension yielding along the length of the strap bracing.

E3.2.1 Designated Energy-Dissipating Mechanism

Yielding of the strap bracing is the designated energy-dissipating mechanism.

E3.2.2 Seismic Design Parameters [Seismic Force Modification Factors and Limitations] for Seismic Force-Resisting System

In the U.S. and Mexico, the seismic response modification coefficient, \( R \), shall be determined in accordance with the applicable building code. For cold-formed steel light frame strap braced wall systems, the design shall comply with this section.

User Note:
In the U.S. and Mexico, the seismic response modification coefficient, \( R \), is generally determined from ASCE 7, Table 12.2-1. The systems specified here are listed as an \( R=4 \) for bearing wall systems in Table 12.2-1, Line A.18. To develop the energy dissipation consistent with this seismic response modification coefficient, the requirements specified in this section must be followed.

In Canada, the seismic force modification factors, \( R_dR_o \), shall be determined in accordance with the applicable building code. For cold-formed steel light frame strap braced wall systems, the design shall comply with this section.

User Note:
In Canada, the seismic force modification factors, \( R_dR_o \), are generally determined from the NBCC. The system specified here is listed as \( R_dR_o=2.47 \) for limited ductility of strap braced walls. To develop the energy dissipation consistent with these factors, the requirements specified in this section must be followed.

E3.2.3 Seismic Load Effects Contributed by Masonry and Concrete Walls

Cold-formed steel light frame strap braced wall systems are permitted to be used to provide resistance to seismic forces in buildings and other structures with masonry or concrete walls, provided the following requirements are met:

(a) The building or other structure is 2 stories or less in height.
(b) The story-to-story wall heights do not exceed 12 ft (3.66 m).
(c) Diaphragms are considered flexible and do not cantilever beyond the outermost supporting strap braced wall.
(d) Combined deflections of diaphragms and walls do not permit per story drift of supported masonry or concrete walls to exceed 0.7% of the story height at LRFD design [LSD factored] load levels.
(e) There are no horizontal out-of-plane offset irregularities as specified by the applicable building code.
E3.3 Shear Strength [Resistance]

E3.3.1 Nominal Strength [Resistance]

For a strap braced wall, the wall nominal strength [resistance] for shear, \( V_n \), shall be determined in accordance with the following:

\[
V_n = T_n w / \sqrt{h^2 + w^2}
\]

where

- \( h \) = Height of the wall
- \( w \) = Length of the wall
- \( T_n \) = Nominal strength [resistance] of the strap braced wall in yielding

\[\text{Eq. E3.3.1-1}\]

\[
T_n = A_g F_y
\]

\[\text{Eq. E3.3.1-2}\]

where

- \( A_g \) = Gross area of the flat strap
- \( F_y \) = Yield stress of the flat strap

**User Note:**

Users are reminded that the designated energy-dissipating mechanism is strap yielding; other traditional tension limit states such as net section fracture are addressed in Section E3.4.

E3.3.2 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 and resistance factors given in this section in accordance with the applicable design method—ASD, LRFD, or LSD as follows:

\[
\Omega_v = 1.67 \quad (ASD)
\]

\[
\phi_v = 0.90 \quad (LRFD)
\]

\[
= 0.90 \quad (LSD)
\]

E3.3.3 Expected Strength [Probable Resistance]

The expected strength [probable resistance] shall be \( R_y A_g F_y \) where \( A_g \) is the gross area of the strap bracing.

E3.4 System Requirements

E3.4.1 Limitations on System

The cold-formed steel light frame strap braced wall system shall conform to the following requirements:

(a) The connection of the strap bracing member to the structural members is designed in accordance with one of the following three methods:

1. Method 1: The connection is welded and configured such that gross cross-section yielding of the strap bracing member governs its strength.

2. Method 2: The connection is configured such that the strap bracing member meets both of the following criteria:

\[
(R_t F_u) / (R_y F_y) \geq 1.2
\]

and,

\[
R_t A_n F_u > R_y A_g F_y
\]

\[\text{Eq. E3.4.1-1}\]

\[\text{Eq. E3.4.1-2}\]
User Note:
Compliance can be demonstrated using published values or through coupon testing. If coupon testing is conducted to determine values, then $R_t$ and $R_y$ become 1.0.

(3) Method 3: The connection is configured such that gross cross-section yielding of the strap bracing member under cyclic loading is demonstrated by tests in accordance with the loading protocol in ASTM E2126.

(b) For strap braced walls where the aspect ratio ($h:w$) exceeds 1.9:1:

(1) A lateral frame analysis of the strap braced wall is required to be performed. The frame analysis is to be based on the assumption of full joint fixity.

User Note:
Commentary Section E3.4.1 provides expressions for a frame analysis with full joint fixity. The purpose of the frame analysis is to determine the moment demand on the chord studs.

(2) In considering the moment along the length of the chord stud, locations that are stiffened by a hold-down or similar attachment at the ends need not be checked for combined axial load and bending.

User Note:
From the frame analysis, the chord stud is designed for combined axial load and bending at the expected strength [probable resistance] of the strap braced wall, in combination with all other applicable loads, in accordance with Section E3.4.2.

(c) Provisions are made for pretensioning, or other methods of installing tension-only strap bracing to guard against loose strap bracing.

(d) Chord studs, or other vertical boundary elements at the ends of wall segments with strap bracing, are anchored such that the bottom track is not required to resist uplift by bending of the track web. Where the track is not designed to resist the horizontal shear force from the strap bracing by compression or tension, the horizontal shear force is resisted by a device connected directly to the strap bracing and anchored directly to the foundation or supporting structural element.

**E3.4.2 Required Strength [Effect Due to Factored Loads] for Seismic Force-Resisting System**

In the U.S. and Mexico, for collectors, connections of strap bracing, chord studs, other vertical boundary elements, hold-downs and anchorage connected thereto, and all other components and connections of the strap braced wall, the required strength shall be determined from the expected strength of the strap braced wall, but need not exceed the load effect determined from the applicable load combinations including seismic loads with overstrength. The available strength of the collectors, connections of strap bracing, chord studs, other vertical boundary elements, hold-downs and anchorage connected thereto, and all other components and connections in the strap braced wall shall be greater than or equal to the required strength.

In Canada, for collectors, connections of strap bracing, chord studs, other vertical boundary elements, hold-downs and anchorage connected thereto, and all other components and connections in the lateral force-resisting system, the effect of factored loads shall be determined from the probable resistance of the strap braced wall taking into consideration the applicable load combinations, but need not exceed the anticipated maximum seismic load effects.
determined with R_dR_o=1.0. The factored resistance of the collectors, connections of strap bracing, chord studs, other vertical boundary elements, hold-downs and anchorage connected thereto, and all other components and connections of the lateral force-resisting system shall be greater than or equal to the effect of factored loads determined from the applicable load combinations.

The effect of eccentricity on required strengths [effect due to factored loads] for connections, chord studs, hold-downs and anchorage shall be considered in the design.

**E3.4.3 Required Strength [Effect Due to Factored Loads] for Foundations**

In the U.S. and Mexico, for foundations, the required strength shall be determined from the seismic load effect and need not include the overstrength factor (Ω_o) nor consider the expected strength of the seismic force-resisting system unless otherwise specified in the applicable building code.

In Canada, for foundations, the effect of factored loads shall be determined from the probable resistance of the seismic force-resisting system, but need not exceed the maximum anticipated seismic load effect determined with R_dR_o=1.0.

**E3.4.4 Design Deflection**

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

**E4 Cold-Formed Steel Special Bolted Moment Frames (CFS–SBMF)**

**E4.1 Scope**

In the U.S. and Mexico, Cold-Formed Steel–Special Bolted Moment Frame (CFS–SBMF) systems shall be designed in accordance with this section. This Standard does not have provisions for this system that are applicable in Canada.

**E4.2 Basis of Design**

Cold-Formed Steel–Special Bolted Moment Frame (CFS–SBMF) systems are expected to withstand inelastic friction and bearing deformations at the bolted beam-to-column connections.

**E4.2.1 Designated Energy-Dissipating Mechanism**

The designated energy-dissipating mechanism is the beam-to-column connection.

**E4.2.2 Seismic Design Parameters for Seismic Force-Resisting System**

In the U.S. and Mexico, the seismic response modification coefficient, R, shall be determined in accordance with the applicable building code. For cold-formed steel special bolted moment frames, the design shall comply with this section.

**User Note:**
In the U.S. and Mexico, the seismic response modification coefficient, R, is generally determined from ASCE 7, Table 12.2-1. The systems specified here are listed as an R=3.5 for moment-resisting frame systems in Table 12.2-1, Line C.12. To develop the energy dissipation consistent with this seismic response modification coefficient, the requirements specified in this section must be followed.
E4.2.3 Seismic Load Effects Contributed by Masonry and Concrete Walls

Seismic load effects contributed by masonry and concrete walls shall not be permitted to be resisted by cold-formed steel special bolted moment frames.

E4.3 Strength

The nominal strength for shear shall be determined in accordance with AISI S100. Where required to determine the nominal strength for shear, for limit states within the same member from which the required strength is determined, the expected yield stress, $R_{re}R_{cf}F_y$, and the expected tensile strength, $R_tF_u$, are permitted to be used in lieu of $F_y$ and $F_u$ respectively, where $F_u$ is the specified minimum tensile strength and $R_t$ is the ratio of the expected tensile strength to the specified minimum tensile strength, $F_u$, of that material.

E4.3.1 Required Strength

The required strength for shear of the connection shall be based on the LRFD load combinations in the applicable building code using the seismic load effect including overstrength. In determining the seismic load effect including overstrength, the effect of horizontal seismic forces including overstrength, $E_{mh}$, shall be taken as stipulated by Sections E4.3.1.1 and E4.3.1.2. The horizontal seismic load effect including overstrength need not exceed $\Omega_oE_h$.

E4.3.1.1 Beams and Columns

The required strength of beams and columns in CFS-SBMF systems shall be determined from the expected moment developed at the bolted connection. The expected shear, $V_e$, shall be determined in accordance with Section E4.3.3.

E4.3.1.2 Bolt Bearing Plates

Bolt bearing plates shall be welded to the beam web and be designed for the following required shear strength, $V_{bp}$:

$$V_{bp} = \frac{V_e}{N} \left( \frac{t_p}{t_w + t_p} \right)$$

(Eq. E4.3.1.2-1)

where

- $t_p =$ Thickness of bolt bearing plate
- $t_w =$ Thickness of beam web
- $V_e =$ Expected strength of the bolted connection, as determined in Section E4.3.3
- $N =$ 1 for single-channel beams
  = 2 for double-channel beams

E4.3.2 Available Strength

The available strength for shear shall be determined from the nominal strength using the applicable resistance factors given in AISI S100 in accordance with the LRFD load combinations.
### E4.3.3 Expected Strength

The expected shear strength, $V_e$, shall be determined as follows:

$$V_e = V_S + V_B$$  \hspace{1cm} (Eq. E4.3.3-1)

where

- $V_S =$ Column shear corresponding to the slip strength of the bolt group
- $V_B =$ Connection bearing component of column shear corresponding to the displacement, $\Delta$

**(1) Slip Component of Column Shear, $V_S$**

The value of $V_S$ shall be determined as follows:

$$V_S = C_S k N T / h$$  \hspace{1cm} (Eq. E4.3.3-2)

where

- $C_S =$ Value from Table E4.3.3-1
- $k =$ Slip coefficient
  - $= 0.33$
- $N =$ 1 for single-channel beams
  - $= 2$ for double-channel beams
- $T =$ 10 kips (44.5 kN) for 1-in. (25.4-mm) diameter bolts, unless the use of a higher value is approved
- $h =$ Height from column base to center line of beam

**(2) Bearing Component of Column Shear, $V_B$**

The value of $V_B$ shall be determined as follows:

$$\left( \frac{V_B}{V_{B,\text{max}}} \right)^2 + \left( 1 - \frac{\Delta_B}{\Delta_{B,\text{max}}} \right)^{1.43} = 1$$  \hspace{1cm} (Eq. E4.3.3-3)

where

- $V_{B,\text{max}} =$ Column shear producing the bearing strength of a bolt group
  - $= C_B N R_0 / h$  \hspace{1cm} (Eq. E4.3.3-4)
- $\Delta =$ Design story drift
- $\Delta_B =$ Component of design story drift causing bearing deformation in a bolt group
  - $= \Delta - \Delta_S - \sum_{i=1}^{n} \left( \frac{M_{e,i}}{n_i} \right) / K$  \hspace{1cm} (Eq. E4.3.3-5)
- $\Delta_{B,\text{max}} =$ Component of design story drift corresponding to the deformation of the bolt group at maximum bearing strength
  - $= C_{B,\text{DB}} h$  \hspace{1cm} (Eq. E4.3.3-6)
- $\Delta_S =$ Component of design story drift corresponding to bolt slip deformation
  - $= C_{DB} h_{05}$  \hspace{1cm} (Eq. E4.3.3-7)

$C_B$, $C_{DS}$, and $C_{B,0} =$ Values from Table E4.3.3-1

$C_{DB} =$ Value from Table E4.3.3-2
d = Bolt diameter  
h_{os} = Hole oversize  
K = Elastic lateral stiffness of the frame line  
M_{e} = Expected moment at a bolt group  
n = Number of columns in a frame line  
R_{0} = Smallest value of dtR_{t}F_{u} of connected components  
F_{u} = Tensile strength of connected component  
t = Thickness of connected component  
R_{t} = Ratio of expected tensile strength to specified minimum tensile strength

Alternate methods of calculating V_{S} and V_{B} are permitted if such methods are acceptable to the authority having jurisdiction.

**Table E4.3.3-1**  
Values of Coefficients C_{S}, C_{DS}, C_{B}, and C_{B,0}

<table>
<thead>
<tr>
<th>Bolt spacing, in.</th>
<th>C_{S} (ft)</th>
<th>C_{DS} (1/ft)</th>
<th>C_{B} (ft)</th>
<th>C_{B,0} (in./ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2½ 3</td>
<td>2.37</td>
<td>5.22</td>
<td>4.20</td>
<td>0.887</td>
</tr>
<tr>
<td>3 6</td>
<td>3.34</td>
<td>3.61</td>
<td>5.88</td>
<td>0.625</td>
</tr>
<tr>
<td>3 10</td>
<td>4.53</td>
<td>2.55</td>
<td>7.80</td>
<td>0.475</td>
</tr>
<tr>
<td>2½ 3</td>
<td>2.84</td>
<td>4.66</td>
<td>5.10</td>
<td>0.792</td>
</tr>
<tr>
<td>3 6</td>
<td>3.69</td>
<td>3.44</td>
<td>6.56</td>
<td>0.587</td>
</tr>
<tr>
<td>3 10</td>
<td>4.80</td>
<td>2.58</td>
<td>8.50</td>
<td>0.455</td>
</tr>
</tbody>
</table>

**Table E4.3.3-2**  
Bearing Deformation Adjustment Factor C_{DB}

<table>
<thead>
<tr>
<th>Relative Bearing Strength, R_{BS}</th>
<th>0.0</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_{DB}</td>
<td>1.00</td>
<td>1.10</td>
<td>1.16</td>
<td>1.23</td>
<td>1.33</td>
<td>1.46</td>
<td>1.66</td>
<td>2.00</td>
</tr>
</tbody>
</table>

where

Relative Bearing Strength (R_{BS}) = (tF_{u})(weaker)/(tF_{u})(stronger), where weaker components correspond to that with a smaller tF_{u} value.

t = Thickness of beam or column component

F_{u} = Tensile strength of beam or column
E4.4 System Requirements

The Cold-Formed Steel–Special Bolted Moment Frame (CFS-SBMF) systems shall conform to the requirements in this section.

E4.4.1 Limitations on System

The Cold-Formed Steel–Special Bolted Moment Frames (CFS-SBMF) systems shall conform to the following requirements:

(a) CFS–SBMF systems are limited to one-story structures, no greater than 35 ft (10.7 m) in height, without column splices.

(b) The CFS–SBMF engages all columns.

(c) All columns shall be designed and constructed as pin-based.

(d) A single size and length beam and single size and length column with the same bolted moment connection detail are used for each frame.

(e) The frame is supported on a level floor or foundation.

(f) For structures having a period shorter than $T_S$, as defined in the applicable building code, alternate methods of computing the design story drift, $\Delta$, are permitted, provided such methods are acceptable to the authority having jurisdiction.

(g) $P-\Delta$ effects are considered in accordance with the requirements of the applicable building code.

E4.4.2 Beams

Beams in the Cold-Formed Steel–Special Bolted Moment Frames (CFS-SBMF) system shall conform to the following requirements:

(a) Beams in CFS–SBMF systems are ASTM A653 Grade 55 galvanized cold-formed steel C-section members with lips, designed in accordance with Chapter C of AISI S100.

(b) The beams have a minimum design thickness of 0.105 in. (2.67 mm).

(c) The beam depth is not less than 12 in. (305 mm) or greater than 20 in. (508 mm).

(d) The flat depth-to-thickness ratio of the web does not exceed $6.18 \sqrt{E/F_y}$.

(e) Where single C-section beams are used, torsional effects are accounted for in the design.

E4.4.3 Columns

Columns in the Cold-Formed Steel–Special Bolted Moment Frames (CFS-SBMF) system shall conform to the following requirements:

(a) Columns in CFS–SBMF systems are cold-formed steel hollow structural section (HSS) members painted with a standard industrial finished surface, and designed in accordance with Chapter C of AISI S100. Hollow structural section (HSS) columns are permitted to be ASTM A500 Grade B and C, and ASTM A1085 materials.

(b) The column depth and width are not less than 8 in. (203 mm) or greater than 12 in. (305 mm).

(c) The flat depth-to-thickness ratio does not exceed $1.40 \sqrt{E/F_y}$. 
**E4.4.4 Connections, Joints and Fasteners**

Connections, joints and fasteners that are part of the seismic force-resisting system shall meet the requirements of AISI S100 except as modified in this section. Connections for members that are part of the seismic force-resisting system shall be configured such that a ductile limit-state in the member or at the joint controls the design.

**E4.4.4.1 Bolted Joints**

Bolts shall be high-strength bolts, and bolted joints shall not be designed to share load in combination with welds. The bearing strength of bolted joints shall be provided using standard holes or short-slotted holes perpendicular to the line of force, unless an alternative hole-type is specified by a registered design professional.

**E4.4.4.1.1 Beam-to-Column Connections**

Beam-to-column connections in the Cold-Formed Steel–Special Bolted Moment Frame (CFS-SBMF) systems shall conform to the following requirements:

(a) Beam-to-column connections in CFS–SBMF systems are bolted connections with 1-in. (25.4-mm) diameter snug-tightened high-strength bolts.

(b) The bolt spacing and edge distance are in accordance with the limits of Section E3 of AISI S100.

(c) The 8-bolt configuration in Table E4.3.1-1 is used.

(d) The faying surfaces of the beam and column in the bolted moment connection region are free of lubricants or debris.

**E4.4.4.1.2 Bolt Bearing Plates**

Bolt bearing plates in the Cold-Formed Steel–Special Bolted Moment Frame (CFS-SBMF) systems shall conform to the following requirements:

(a) The use of bolt bearing plates on beam webs in CFS–SBMF systems are permitted to increase the bearing strength of the bolt.

(b) Bolt bearing plates are welded to the beam web.

(c) The edge distance of bolts are in accordance with the limits of Section E3 of AISI S100.

**E4.4.4.2 Welded Joints**

Welded joints are permitted to join members that are a part of the seismic force-resisting system, in accordance with AISI S100.

**E4.4.4.3 Other Joints and Connections**

Alternative joints and connections are permitted if the registered design professional demonstrates performance equivalent to the approved joints and connections specified in accordance with Chapter H.
E5 Cold-Formed Steel Light Frame Shear Walls With Wood-Based Structural Panel Sheathing on One Side and Gypsum Board Panel Sheathing on the Other Side

E5.1 Scope

In Canada, cold-formed steel light frame shear walls sheathed with wood-based structural panels on one side and gypsum board panels on the other side shall be designed in accordance with the requirements of this section. This Standard does not have provisions for this system that are applicable in the U.S. and Mexico.

E5.2 Basis of Design

Cold-formed steel light frame shear walls sheathed with wood-based structural panels on one side and gypsum board panels on the other side are expected to withstand seismic demands primarily through deformation in the connections between both the wood-based structural panel and gypsum board panel and cold-formed steel structural members.

E5.2.1 Designated Energy-Dissipating Mechanism

The structural member-to-sheathing connection and the wood-based structural panel and gypsum board panel themselves are the designated energy-dissipating mechanism in this system.

E5.2.2 Seismic Force Modification Factors and Limitations for Seismic Force-Resisting System

The seismic force modification factors, $R_dR_o$, shall be determined in accordance with the applicable building code. For cold-formed steel light frame shear walls sheathed with wood-based structural panels on one side and gypsum board panels on the other side, the design shall comply with this section.

User Note:

In Canada, the seismic force modification factors, $R_dR_o$, are generally determined from the NBCC. The system specified here is listed as $R_dR_o=2.55$ for screw-connected shear walls with wood-based structural panel sheathing on one side and gypsum panels on the other side. To develop the energy dissipation consistent with these factors, the detailing specified in this section must be followed.

For this seismic force-resisting system, gypsum board panel shear walls shall not be used alone to resist lateral loads and the use of gypsum board panels in shear walls shall be limited to structures four stories or less in height, in accordance with the applicable building code. (See Appendix 1 for details.)

E5.2.3 Type I Shear Walls

The design of shear walls that resist seismic loads shall be classified as Type I shear walls in accordance with this section.

Type I shear walls shall be full-height sheathed with hold-downs and anchorage at each end.

E5.2.4 Seismic Load Effects Contributed by Masonry and Concrete Walls

Cold-formed steel light frame shear walls sheathed with wood-based structural panels on
one side and gypsum panels on the other side shall not be used to provide resistance to seismic forces from masonry or concrete walls.

**E5.3 Shear Resistance**

**E5.3.1 Nominal Resistance**

**E5.3.1.1 Type I Shear Walls**

For a Type I shear wall sheathed with wood-based structural panels on one side and gypsum board panels on the other side, the nominal resistance for shear, \( V_n \), shall be determined in accordance with the following:

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

\[
V_n = v_n w \quad \text{(Eq. E5.3.1.1-1)}
\]

where

- \( h \) = Height of the shear wall, ft (m)
- \( w \) = Length of the shear wall, ft (m)
- \( v_n \) = Nominal shear resistance per unit length as specified in Table E1.3-1 lb/ft (kN/m) and Table E5.3-1 and as determined in accordance with Section E5.3.1.1.2, as applicable

The length of a Type I shear wall shall not be less than 24 in. (610 mm).

**E5.3.1.1.1 Both Wall Faces Sheathed With the Same Material and Fastener Spacing**

For a Type I shear wall sheathed with wood-based structural panels on one side and gypsum board panels on the other side having the same material and fastener spacing on opposite faces of the same wall, the nominal resistance, based on Table E1.3-1 and Table E5.3-1, shall be determined by adding the strength from the two opposite faces together.

**Table E5.3-1**

<table>
<thead>
<tr>
<th>Canada</th>
<th>Nominal Shear Resistance ((v_n)) per Unit Length for Seismic Loads for Shear Walls Sheathed With Gypsum Board on One Side of Wall(^{1,2,3}) (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly Description</td>
<td>Maximum Aspect Ratio ((h:w))</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>12.5 mm gypsum board; studs max. 600 mm o.c.</td>
<td>2:1</td>
</tr>
</tbody>
</table>

1. For U.S. Customary Units: 1 mm = 0.0394", 1 m = 3.28 ft, 1 N = 0.225 lb
2. Only where Desigation Thickness is specified as a (min) is substitution with a thicker member permitted.
3. Tabulated values are applicable for short-term load duration only (seismic loads). Gypsum-sheathed shear walls are not permitted for other load durations.

**E5.3.2 Factored Resistance**

The factored resistance \((\phi V_n)\) shall be determined from the nominal resistance using the applicable resistance factor given in this section in accordance with LSD as follows:

\( \phi_v = 0.70 \) (LSD)
E5.3.3 Probable Resistance

The probable resistance \((\Omega_{E}V_{n})\) shall be determined from the nominal resistance in accordance with this section. The expected resistance factor, \(\Omega_{E}\), shall be 1.33 for walls with DFP wood-based structural panel sheathing, OSB wood-based structural panel sheathing, or gypsum board panel sheathing; and 1.45 for walls with CSP wood-based structural panel sheathing.

E5.4 System Requirements

E5.4.1 Type I Shear Walls

E5.4.1.1 Limitations for Tabulated Systems

The Type I shear wall seismic force-resisting system specified in Table E1.3-1 and Table E5.3-1 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) Chord studs, or other vertical boundary elements at the ends of wall segments braced with sheathing, are anchored such that the bottom track is not required to resist uplift by bending of the track web.

(e) Screws for structural members are a minimum No. 8 and comply with ASTM C1513.

(f) Fasteners along the edges in shear panels are placed from panel edges not less than 12.5 mm (1/2 in.).

(g) Fasteners in the field of the panel are installed 12 in. (305 mm) o.c. unless otherwise specified.

(h) Panel thicknesses are taken as minimums.

(i) Panels less than 12-in. (305-mm) wide are not permitted.

(j) Maximum stud spacing is 24 in. (610 mm) on center.

(k) All sheathing edges are attached to structural members or panel blocking.

(l) Where used as panel blocking, flat strap is a minimum thickness of 33 mils with a minimum width of 1-1/2 in. (38.1 mm) and is installed below the sheathing.

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

(n) Wood structural panel sheathing is manufactured using exterior glue and complies with CSA-O121, CSA-O151 or CSA-O325.

(o) Wood structural panel sheathing is permitted to be applied either parallel to or perpendicular to studs.

(p) Wood structural panel sheathing is attached to cold-formed steel structural members with either No. 8 self-tapping screws with a minimum head diameter of 0.285 in. (7.24
mm) or No. 10 self-tapping screws with a minimum head diameter of 0.333 in. (8.46 mm).

(q) Screws used to attach wood structural panel sheathing to cold-formed steel structural members comply with ASTM C1513.

(r) The pull-out resistance of screws is not used to resist seismic forces.

(s) Gypsum board panels comply with ASTM C1396/C1396M.

(t) For gypsum board panels that are applied perpendicular to studs, flat strap is used as panel blocking behind the horizontal joint with in-line blocking between the first two end studs, at each end of the wall. In-line blocking is a stud or track section with the same web depth and minimum thickness as the studs. In-line blocking is attached to each stud with a minimum of one No. 8 screw. For gypsum board panels that are applied parallel to studs, all panel edges are attached to structural members. Unblocked assemblies are permitted provided the nominal resistance values are multiplied by 0.35.

(u) Screws used to attach gypsum board panels shall be in accordance with ASTM C954 or ASTM C1002, as applicable.

E5.4.1.2 Effect of Factored Loads for Chord Studs, Anchorage, and Collectors

For chord studs, other vertical boundary elements, uplift anchorage connected thereto, collectors, and all other components and connections in the lateral force-resisting system that are not part of the designated energy-dissipating mechanism, the effect of factored loads shall be determined from the probable resistance of the seismic force-resisting system, but need not exceed the maximum anticipated seismic load effect determined with \( R_dR_o=1.0 \). The factored resistance of the chord studs, other vertical boundary elements, and uplift anchorage connected thereto, collectors, and all other components and connections in the lateral force-resisting system shall be greater than or equal to the effects of factored loads determined from the applicable load combinations.

E5.4.1.3 Effect of Factored Loads for Foundations

For foundations in Type I shear walls, the effect of factored loads shall be determined from the probable resistance of the seismic force-resisting system, but need not exceed the maximum anticipated seismic load effect determined with \( R_dR_o=1.0 \).

E5.4.1.4 Design Deflection

The deflection of a Type I shear wall shall be determined by principles of mechanics considering the deformation of the sheathing and its attachment, chord studs, hold-downs and anchorage.

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E6 Cold-Formed Steel Light Frame Shear Walls With Gypsum Board or Fiberboard Panel Sheathing

E6.1 Scope

In the U.S. and Mexico, cold-formed steel light frame shear walls sheathed with gypsum board panels or fiberboard panels shall be designed in accordance with this section. This Standard does not have provisions for this system that are applicable in Canada.

E6.2 Basis of Design

Cold-formed steel light frame shear walls sheathed with gypsum board panels or fiberboard panels are expected to withstand seismic demands primarily through deformation in the connection between the sheathing and cold-formed steel structural members.

E6.2.1 Designated Energy-Dissipating Mechanism

The structural member-to-sheathing connection and the sheathing itself are the designated energy-dissipating mechanism in this system.

E6.2.2 Seismic Design Parameters for Seismic Force-Resisting System

The seismic response modification coefficient, R, shall be determined in accordance with the applicable building code. For cold-formed steel light frame shear walls sheathed with gypsum board panels or fiberboard panels, the design shall comply with this section.

User Note:

In the U.S. and Mexico, the seismic response modification coefficient, R, is generally determined from ASCE 7, Table 12.2-1. The systems specified here are listed as an R=2.0 for bearing wall systems in Table 12.2-1, Line A.17, and R=2.5 for building frame systems in Line B.24. To develop the energy dissipation consistent with these seismic response modification coefficients the detailing specified in this section must be followed.

E6.2.3 Type I Shear Walls

The design of shear walls that resist seismic loads shall be classified as Type I shear walls in accordance with this section.

Type I shear walls shall be full-height sheathed with hold-downs and anchorage at each end.

E6.2.4 Seismic Load Effects Contributed by Masonry and Concrete Walls

Cold-formed steel light frame shear walls sheathed with gypsum board panels or fiberboard panels shall not be used to provide resistance to seismic forces from masonry or concrete walls.

E6.3 Shear Strength

E6.3.1 Nominal Strength

E6.3.1.1 Type I Shear Walls

For a Type I shear wall sheathed with gypsum board panels or fiberboard panels, the nominal strength for shear, V_{n,1}, shall be determined in accordance with the following:
For $h/w \leq 2$,

$$V_n = v_nw$$

where

- $h$ = Height of the shear wall, ft (m)
- $w$ = Length of the shear wall, ft (m)
- $v_n$ = Nominal shear strength per unit length as specified in Table E6.3-1 lb/ft (kN/m)

In no case shall the height-to-length aspect ratio ($h/w$) exceed 2:1 for a Type I shear wall sheathed with gypsum board panels or 1:1 for a Type I shear wall sheathed with fiberboard panels.

The length of a Type I shear wall shall not be less than 24 in. (610 mm).

**E6.3.1.1.1 Both Wall Faces Sheathed With the Same Material and Fastener Spacing**

For a Type I shear wall sheathed with gypsum board panels or fiberboard panels having the same material and fastener spacing on opposite faces of the same wall, the nominal strength, based on Table E6.3-1, shall be determined by adding the strength from the two opposite faces together.

**E6.3.1.1.2 More Than a Single Sheathing Material or Fastener Configuration**

For a Type I shear wall sheathed with gypsum board panels or fiberboard panels having more than a single sheathing material or fastener spacing, the nominal strength, based on Table E6.3-1, of the complete wall shall not be permitted to be determined by adding the strength from the different walls. Rather, it shall be determined in accordance with this section.

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

For a Type I shear wall sheathed with gypsum board panels or fiberboard panels having more than a single sheathing material or fastener configuration on opposite faces of the wall, the nominal strength 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.

**User Note:**

For walls with multiple layers of sheathing on an individual face of a wall, insufficient research exists to provide a definitive solution. Accounting for only the innermost layer when determining the strength of the panel is assumed to be conservative, but has not been verified by testing.
Table E6.3-1

<table>
<thead>
<tr>
<th>Assembly Description</th>
<th>Maximum Aspect Ratio (h:w)</th>
<th>Fastener Spacing at Panel Edges/Field (in.)</th>
<th>Designation Thickness of Stud and Track (mils)</th>
<th>Required Sheathing Screw Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>⁷/₈” gypsum board;</td>
<td>2:1</td>
<td>290</td>
<td>-</td>
<td>33</td>
</tr>
<tr>
<td>studs max. 24” o.c.</td>
<td>4/4</td>
<td>425</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>⁷/₈” fiberboard;</td>
<td>1:1</td>
<td>-</td>
<td>425</td>
<td>33</td>
</tr>
<tr>
<td>studs max. 24” o.c.</td>
<td>4/12</td>
<td>295</td>
<td>615</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>8/12</td>
<td>230</td>
<td>670</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4/6</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3/6</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2/6</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. For SI: 1” = 25.4 mm, 1 ft = 0.305 m, 1 lb = 4.45 N
2. See Section E6.3.1.1.1 and Section E6.3.1.1.2 for requirements for sheathing applied to both sides of wall.
3. For gypsum board or fiberboard sheathed shear walls, tabulated values are applicable for short-term load duration only (seismic loads).

E6.3.2 Available Strength

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

- $\Omega_v = 2.50$ (ASD)
- $\phi_v = 0.60$ (LRFD)

E6.3.3 Expected Strength

The expected strength ($\Omega_EV_n$) shall be determined from the nominal strength in accordance with this section. The expected strength factor, $\Omega_E$, shall be equal to 1.5 for shear walls with gypsum board or fiberboard panel sheathing.

E6.4 System Requirements

E6.4.1 Type I Shear Walls

E6.4.1.1 Limitations for Tabulated Systems

The Type I shear wall seismic force-resisting system specified in Table E6.3-1 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) Chord studs, or other vertical boundary elements at the ends of wall segments braced
with sheathing, are anchored such that the bottom track is not required to resist uplift by bending of the track web.

(e) Screws for structural members are a minimum No. 8 and comply with ASTM C1513.

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

(g) Fasteners in the field of the panel are installed 12 in. (305 mm) o.c. unless otherwise specified.

(h) Panel thicknesses are taken as minimums.

(i) Panels less than 12-in. (305-mm) wide are not permitted.

(j) Maximum stud spacing is 24 in. (610 mm) on center.

(k) All sheathing edges are attached to structural members or panel blocking.

(l) Where used as panel blocking, flat strap is a minimum thickness of 33 mils with a minimum width of 1-1/2 in. (38.1 mm) and is installed below the sheathing.

(m) Gypsum board panels comply with ASTM C1396/C1396M.

(n) For gypsum board panels that are applied perpendicular to studs, flat strap is used as panel blocking behind the horizontal joint with in-line blocking between the first two end studs, at each end of the wall. In-line blocking is a stud or track section with the same web depth and minimum thickness as the studs. In-line blocking is attached to each stud with a minimum of one No. 8 screw. For gypsum board panels that are applied parallel to studs, all panel edges are attached to structural members. Unblocked assemblies are permitted provided the nominal resistance values are multiplied by 0.35.

(o) Screws used to attach gypsum board panels are in accordance with ASTM C954 or ASTM C1002, as applicable.

(p) Fiberboard panels comply with ASTM C208.

(q) For fiberboard panels that are applied perpendicular to studs, flat strap is used as panel blocking behind the horizontal joint and with in-line blocking between the first two end studs, at each end of the wall. In-line blocking is a stud or track section with the same web depth and minimum thickness as the studs. In-line blocking is attached to each stud with a minimum of one No. 8 screw. For fiberboard panels applied parallel to studs, all edges are attached to structural members.

(r) Screws used to attach fiberboard panels comply 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 in. (10.9 mm). Screws are to be driven so that their flat bearing surface is flush with the surface of the sheathing.

(s) The pull-out resistance of screws is not used to resist seismic forces.

E6.4.1.2 Required Strength for Chord Studs, Anchorage, and Collectors

For collectors, chord studs, other vertical boundary elements, hold-downs and anchorage connected thereto, and all other components and connection of the shear wall that are not part of the designated energy-dissipating mechanism, the required strength shall be determined from the expected strength of the shear wall, but need not exceed the load effect determined from applicable load combinations including seismic load with overstrength. The available strength of the collectors, chord studs, other vertical boundary
elements, hold-downs and anchorage connected thereto, and all other components and connections in the shear wall shall be greater than or equal to the required strength.

**E6.4.1.3 Required Strength for Foundations**

For foundations, the required strength shall be determined from the seismic load effect and need not include the overstrength factor \( (\Omega_o) \) nor consider the expected strength of the seismic force-resisting system unless otherwise specified in the applicable building code.

**E6.4.1.4 Design Deflection**

The deflection of a Type I shear wall shall be determined by principles of mechanics considering the deformation of the sheathing and its attachment, chord studs, hold-downs and anchorage.
E7 Conventional Construction Cold-Formed Steel Light Frame Strap Braced Wall Systems

E7.1 Scope

In Canada, conventional construction cold-formed steel light frame strap braced wall systems shall be designed in accordance with the requirements of this section. This Standard does not have provisions for this system that are applicable in the U.S. and Mexico.

E7.2 Basis of Design

Conventional construction cold-formed steel light frame strap braced wall systems are expected to withstand seismic demands primarily through generalized ductility in the system.

E7.2.1 Designated Energy-Dissipating Mechanism

There is no designated energy-dissipating mechanism for this system.

E7.2.2 Seismic Force Modification Factors and Limitations for Seismic Force-Resisting System

The seismic force modification factors, \( R_d R_o \), shall be determined in accordance with the applicable building code. For conventional construction cold-formed steel light frame strap braced wall systems, the design shall comply with this section.

User Note: In Canada, seismic force modification factors, \( R_d R_o \), are generally determined from the NBCC. The system specified here is listed as \( R_d R_o = 1.56 \) for conventional construction strap braced walls.

E7.2.3 Wall Aspect Ratio

The aspect ratio (h:w) of a conventional construction strap braced wall shall not exceed 2:1.

E7.2.4 Seismic Load Effects Contributed by Masonry and Concrete Walls

Seismic load effects contributed by masonry and concrete walls shall not be permitted to be resisted by conventional construction cold-formed steel light frame strap braced wall systems.

E7.3 Shear Resistance

E7.3.1 Nominal Resistance

For a conventional construction strap braced wall, the wall nominal resistance for shear, \( V_n \), shall be determined by the governing limit state in the wall in accordance with AISI S100.

E7.3.2 Factored Resistance

The factored resistance \( (\phi V_n) \) shall be determined from the nominal resistance using the applicable resistance factor in AISI S100 for the governing limit state.
E7.4 System Requirements

E7.4.1 Limitations on System

The conventional construction cold-formed steel light frame strap braced wall system shall conform to Section E3.4.1(b) and Section E3.4.1(c).

E7.4.2 Effect of Eccentricity

The effect of eccentricity on effect of factored loads for connections, chord studs, and anchorages shall be considered in the design.

E7.4.3 Design Deflection

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

F1 General

F1.1 Scope

In the U.S. and Mexico, the design of diaphragms that resist seismic loads shall comply with the requirements of this section.

F1.2 Design Basis

Diaphragms work to collect and distribute inertial forces to the seismic force-resisting system. They are not intended to work as a prescribed energy-dissipating mechanism.

F1.3 Required Strength

For the purposes of determining required strength, the diaphragm shall be designated as rigid, semi-rigid, or flexible as specified in the applicable building code. Where stiffness is required for analysis, it shall be determined using mechanical properties of the diaphragm, as required by the applicable building code.

F1.3.1 Diaphragm Stiffness

Diaphragm stiffness shall be determined from the applicable building code or rational engineering analysis.

User Note:
A conservative approach is to calculate the required strength first assuming a rigid diaphragm and then assuming a flexible diaphragm, taking the worst-case scenario between the two.

F1.3.2 Seismic Load Effects Including Overstrength

Where required by the applicable building code, seismic load effects including overstrength shall be considered.

F1.4 Shear Strength

F1.4.1 Nominal Strength

The shear resistance of diaphragms shall be determined based on principles of mechanics considering fastener strength and the shear resistance of the diaphragm material. Where determined by the principles of mechanics, the nominal strength shall be the maximum resistance that the diaphragm is capable of developing.

F1.4.1.1 Diaphragms Sheathed With Wood Structural Panels

Alternatively for diaphragms sheathed with wood structural panels, the nominal strength is permitted to be determined by Section F2.

F1.4.2 Available Strength

The available strength ($\phi_v V_n$ or $V_n/\Omega_v$) shall be determined from the nominal strength using the applicable safety factors and resistance factors given in AISI S100 for diaphragms.
sheathed with profiled steel panels; Section F2.4.2 for diaphragms sheathed with wood structural panels; and the applicable building code for diaphragms with other approved materials.

F2 Cold-Formed Steel Diaphragms Sheathed With Wood Structural Panels

F2.1 Scope

Where the seismic force-resisting system is designed and constructed in accordance with Chapter E and the diaphragm is composed of cold-formed steel light frame construction sheathed with wood structural panels, the diaphragm shall be designed in accordance with this section.

F2.2 Additional Design Requirements

F2.2.1 Seismic Detailing Requirements

Where the applicable seismic response modification coefficient, R, is taken equal to or less than 3, in accordance with the applicable building code, the design shall comply with these requirements exclusive of those in Section F2.5.

Where the applicable seismic response modification coefficient, R, is taken greater than 3, in accordance with the applicable building code, the design shall comply with these requirements inclusive of those in Section F2.5.

F2.2.2 Seismic Load Effects Contributed by Masonry and Concrete Walls

Cold-formed steel floor and roof members sheathed with wood structural panels are permitted to be used in diaphragms to resist horizontal seismic forces contributed by masonry or concrete walls in structures two stories or less in height, provided such forces do not result in torsional force distribution through the diaphragm.

Wood structural panel sheathing in diaphragms supporting masonry or concrete walls shall have all unsupported edges blocked.

F2.3 Required Strength

The required strength of diaphragms and diaphragm chords shall be in accordance with the applicable building code. The required strength for collectors shall be determined from the expected strength of the seismic force-resisting system, but need not exceed the seismic load effect including overstrength.

F2.3.1 Diaphragm Stiffness

Stiffness for cold-formed steel diaphragms sheathed with wood structural panels shall be determined from the applicable building code or rational engineering analysis.

F2.4 Shear Strength

F2.4.1 Nominal Strength

The nominal strength of diaphragms sheathed with wood structural panels is permitted to be determined in accordance with Eq. F2.4.1-1 subject to the requirements in Section F2.4.1.1.
\[ V_n = v_n L \quad (Eq. \text{ F2.4.1-1}) \]

where

- \( L = \text{Diaphragm resistance length, in ft (m)} \)
- \( v_n = \text{Nominal shear strength per unit length as specified in Table F2.4-1, lb/ft (kN/m)} \)

**F2.4.1.1 Requirements for Tabulated Systems**

The following requirements shall apply to diaphragms sheathed with wood structural panels:

(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 tracks 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 and DOC 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 comply with ASTM C1513.

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

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

(k) Maximum joist spacing is 24 in. (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 blocking, flat strap is a minimum thickness of 33 mils with a minimum width of 1-1/2 in. (38.1 mm) and is installed below the sheathing.

(n) Where diaphragms are designed as blocked, the screws are installed through the sheathing to the blocking.

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

**F2.4.2 Available Strength**

The available strength \((\phi_v V_n \text{ or } V_n/\Omega_v)\) shall be determined from the nominal strength...
using the applicable safety factors and resistance factors given in this section in accordance
with the applicable design method – ASD or LRFD as follows:

\[ \Omega_v = 2.50 \quad (ASD) \]
\[ \phi_v = 0.60 \quad (LRFD) \]

**F2.4.3 Design Deflection**

The deflection of a diaphragm with wood structural panel sheathing shown in Table F2.4-1 shall be determined by principles of mechanics considering the deformation of the sheathing and its attachment, chords and collectors.

### Table F2.4-1
Nominal Shear Strength \((v_n)\) per Unit Length for Diaphragms Sheathed 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</td>
<td>Screws spaced maximum of 6 in. on all supported edges</td>
</tr>
<tr>
<td></td>
<td></td>
<td>edges and at all continuous panel</td>
<td>Load perpendicular to unblocked edges and continuous panel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>edges (in.)</td>
<td>joints</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 4 2.5 2</td>
<td>All other configurations</td>
</tr>
<tr>
<td></td>
<td>Screw spacing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>at all other</td>
<td>6 6 4 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>panel edges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural I</td>
<td>3/8</td>
<td>768 1022 1660 2045</td>
<td>685 510</td>
</tr>
<tr>
<td></td>
<td>7/16</td>
<td>768 1127 1800 2255</td>
<td>755 565</td>
</tr>
<tr>
<td></td>
<td>15/32</td>
<td>925 1232 1970 2465</td>
<td>825 615</td>
</tr>
<tr>
<td>C-D, C-C and other</td>
<td>3/8</td>
<td>690 920 1470 1840</td>
<td>615 460</td>
</tr>
<tr>
<td>graded wood</td>
<td>7/16</td>
<td>760 1015 1620 2030</td>
<td>680 505</td>
</tr>
<tr>
<td>structural panels</td>
<td>15/32</td>
<td>832 1110 1770 2215</td>
<td>740 555</td>
</tr>
</tbody>
</table>

1. For SI: 1" = 25.4 mm, 1 ft = 0.305 m, 1 lb = 4.45 N
2. For diaphragms sheathed with wood structural panels, tabulated \(R_n\) values are applicable for short-term load duration (seismic loads).

**F2.5 Requirements Where the Seismic Response Modification Coefficient, \(R\), is Greater Than Three**

Where the seismic response modification coefficient, \(R\), used to determine the lateral forces is taken greater than 3 and the diaphragm is constructed with cold-formed steel framing sheathed with wood structural panels, the diaphragm shall meet the additional requirements in this section.
F2.5.1 Open Front Structures

Open front structures with rigid diaphragms sheathed with wood structural panels resulting in torsional force distribution shall be limited by the following:
(a) The length of the diaphragm normal to the open side cannot exceed 25 ft (7.62 m), and the aspect ratio (length:width) is less than 1:1 for one-story structures or 2:3 for structures over one story in height, where the length dimension of the diaphragm is perpendicular to the opening.
(b) Where calculations show that diaphragm deflections can be tolerated, the length normal to the opening is permitted to be increased to an aspect ratio (length:width) not greater than 3:2.

F2.5.2 Member Requirements

Wood structural panel sheathing shall be arranged so that the minimum panel width is not less than 24 in. (610 mm).

F3 Other Diaphragms

[Reserved]
G. QUALITY CONTROL AND QUALITY ASSURANCE

G1 Cold-Formed Steel Light Frame Shear Walls Sheathed With Wood Structural Panels

Quality control and quality assurance for cold-formed steel light frame shear walls sheathed with wood structural panels rated for shear resistance shall be in accordance with Chapter D of AISI S240.

G2 Cold-Formed Steel Light Frame Shear Walls Sheathed with Steel Sheets

Quality control and quality assurance for cold-formed steel light frame shear walls with steel sheet sheathing shall be in accordance with Chapter D of AISI S240.

G3 Cold-Formed Steel Light Frame Strap Braced Wall Systems

Quality control and quality assurance for cold-formed steel light frame strap braced walls shall be in accordance with Chapter D of AISI S240.

G4 Cold-Formed Steel Special Bolted Moment Frames (CFS–SBMF)

The fabricator shall provide quality control procedures to the extent that the fabricator deems necessary to ensure that the work is performed in accordance with this Standard. In addition to the fabricator’s quality control procedures, material and workmanship at all times are permitted to be subject to inspection by qualified inspectors representing the owner. If such inspection by the owner’s representatives will be required, it shall be so stated in the construction documents.

G4.1 Cooperation

Where possible, the inspection by owner’s representatives shall be made at the fabricator’s plant. The fabricator shall cooperate with the inspector, permitting access for inspection to all places where work is being done. The owner’s inspector shall schedule this work for minimum interruption to the work of the fabricator.

G4.2 Rejections

Material or workmanship not in conformance with the provisions of this Standard are permitted to be rejected at any time during the progress of the work.

The fabricator shall receive copies of all reports furnished to the owner by the inspection agency.

G4.3 Inspection of Welding

The inspection of welding shall be in accordance with the provisions of AWS D1.1 and AWS D1.3, as applicable. When visual inspection is required to be performed by AWS-certified welding inspectors, it shall be specified in the construction documents. When nondestructive testing is required, the process, extent, and standards of acceptance shall be defined in the construction documents.
G4.4 Inspection of Bolted Connections

Connections shall be inspected to verify that the fastener components are as specified and that the joint plies have been drawn into firm contact. A representative sample of bolts shall be evaluated using an ordinary spud wrench to ensure that the bolts in the connections have been tightened to a level equivalent to that of the full effort of a worker equipped with such wrench.

G4.5 Identification of Steel

The fabricator shall be able to demonstrate by a written procedure and by actual practice a method of material identification, visible at least through the “fit-up” operation, for the main structural elements of each shipping piece.

G5 Cold-Formed Steel Light Frame Shear Walls Sheathed With Wood-Based Structural Panels and Gypsum Board Panels in Combination

Quality control and quality assurance for cold-formed steel light frame shear walls sheathed with wood-based structural panels and gypsum board panels in combination shall be in accordance with Chapter D of AISI S240.

G6 Cold-Formed Steel Light Frame Shear Walls Sheathed With Gypsum Board or Fiberboard Panels

Quality control and quality assurance for cold-formed steel light frame shear walls sheathed with gypsum board panels or fiberboard panels shall be in accordance with Chapter D of AISI S240.
H. Use of Substitute Components and Connections in Seismic Force-Resisting Systems

The substitution of components or connections into one of the seismic force-resisting systems specified in Chapter E shall be in accordance with the applicable building code and subject to the approval of the authority having jurisdiction.
APPENDIX 1, SEISMIC FORCE MODIFICATION FACTORS AND LIMITATIONS IN CANADA

1.1 Scope and Applicability

This appendix applies to Canada. It contains design coefficients, system limitations and design parameters for seismic force-resisting systems that are included in this Standard, but are not yet defined in the applicable building code. The values presented in this appendix shall only be used where neither the applicable building code nor the NBCC contain such values.

1.2 Seismic Force Modification Factors and Limitations in Canada

In Canada, the ductility-related seismic force modification factor, $R_d$, the overstrength-related seismic force modification factor, $R_o$, and restrictions for cold-formed steel seismic force-resisting systems that are to be designed for seismic loads in conjunction with the applicable building code shall be as listed in Table 1.2-1. In addition, gypsum board shear walls shall not be used alone to resist lateral loads and the use of gypsum board in shear walls shall be limited to structures four stories or less in height, in accordance with Table 1.2-2.
Table 1.2-1
Canada
Design Coefficients and Factors for Seismic Force-Resisting Systems in Canada

<table>
<thead>
<tr>
<th>Type of Seismic Force-Resisting System</th>
<th>Rd</th>
<th>Ro</th>
<th>Building Height (m) Limitations</th>
<th>Cases Where IEF_aS_a(0.2)</th>
<th>Cases Where IEF_aS_a(1.0)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt; 0.2</td>
<td>≥0.2 to &lt;0.35</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≥0.35 to ≤0.75</td>
<td>&gt;0.75</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;0.3</td>
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<tr>
<td>Shear Walls 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screw-connected shear walls: wood-based structural panel</td>
<td>2.5</td>
<td>1.7</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screw-connected shear walls: wood based structural and gypsum panels in combination</td>
<td>1.5</td>
<td>1.7</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel sheet sheathed shear walls</td>
<td>2.0</td>
<td>1.3</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strap Braced Walls 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited ductility braced wall 4</td>
<td>1.9</td>
<td>1.3</td>
<td>20</td>
<td>20</td>
<td>20</td>
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<tr>
<td>Conventional construction5</td>
<td>1.2</td>
<td>1.3</td>
<td>15</td>
<td>NP</td>
<td>NP</td>
</tr>
<tr>
<td>Other Cold-Formed Steel Seismic Force-Resisting System(s)</td>
<td>1.0</td>
<td>1.0</td>
<td>15</td>
<td>NP</td>
<td>NP</td>
</tr>
</tbody>
</table>

1. NP = Not Permitted.
2. Seismic Force-Resisting System specifically detailed for ductile seismic performance. Capacity-based design approach is applied, assuming the sheathing connections act as the energy-dissipating element (See Section E1, Section E2 and Section E5, as applicable).
3. Seismic Force-Resisting System specifically detailed so that all members of the bracing system are subjected primarily to axial forces. The eccentric effect due to single-sided bracing is neglected for purposes of this classification, but is considered in accordance with Section E3 and Section E7.
4. Seismic Force-Resisting System specifically detailed for ductile seismic performance. Capacity-based design approach is applied, assuming the braces act as the energy-dissipating element (gross cross-section yielding). See Section E3.
5. Lateral system not specifically detailed for ductile seismic performance (Capacity-based design approach not required. See Section E7).

Table 1.2-2
Canada
Maximum Percentage of Total Shear Forces Resisted by Gypsum Board in a Story

<table>
<thead>
<tr>
<th>Story</th>
<th>Percentage of Shear Forces</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stories in Building 4 3 2 1</td>
</tr>
<tr>
<td>4th</td>
<td>80  -  -  -</td>
</tr>
<tr>
<td>3rd</td>
<td>60  80  -  -</td>
</tr>
<tr>
<td>2nd</td>
<td>40  60  80  -</td>
</tr>
<tr>
<td>1st</td>
<td>40  40  60  80</td>
</tr>
</tbody>
</table>

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AISI STANDARD

Commentary on
North American Standard
for Seismic Design of
Cold-Formed Steel
Structural Systems

2015 Edition With Supplement 1
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 seismic design for cold-formed steel structures. 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 on the Standard.

With anticipated improvements in understanding of the behavior of cold-formed steel 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 registered professional engineer. Indeed, in many jurisdictions, such a 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

The American Iron and Steel Institute (AISI) Committee on Framing Standards has developed this first edition of the North American Standard for Seismic Design of Cold-Formed Steel Structural Systems (hereinafter referred to as this Standard) in 2015. This Standard is intended to address the design and construction of lateral force-resisting systems used in buildings and other structures framed from cold-formed steel structural members and connections appropriate for seismic design. This Standard provides the lateral capacity and necessary detailing for specific seismic force-resisting systems such that appropriate seismic response factors may be applied in the analysis and design. In this first edition, the material represents a merging of AISI S110, Standard for Seismic Design of Cold-Formed Steel Structural Systems – Special Bolted Moment Frames, 2007 Edition with Supplement No. 1-09, and the seismic portions of AISI S213, North American Standard for Cold-Formed Steel Framing – Lateral Design, 2007 Edition with Supplement No. 1-09. In addition, some of the seismic design requirements stipulated in this Standard are drawn from ANSI/AISC 341-10, Seismic Provisions for Structural Steel Buildings, developed by the American Institute of Steel Construction. The application of this Standard should be in conjunction with AISI S100, North American Specification for the Design of Cold-Formed Steel Structural Members (hereinafter referred to as AISI S100), and AISI S240, North American Standard for Cold-Formed Steel Framing (hereinafter referred to as AISI S240).

The Lateral Design Subcommittee of the AISI Committee on Framing Standards is responsible for the ongoing development of this Standard. The AISI Committee on Framing Standards gives the final approval of this document through an ANSI-accredited balloting process.

The Committee acknowledges and is grateful to the numerous engineers, researchers, producers and others who have contributed to the body of knowledge on these subjects. AISI further acknowledges the permission of the American Institute of Steel Construction for adopting provisions from its Seismic Provisions for Structural Steel Buildings.

In the second printing of this standard, Supplement 1 to AISI S400-15-C is incorporated.

American Iron and Steel Institute
November 2015
Updated September 2016
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**COMMENTARY ON NORTH AMERICAN STANDARD FOR SEISMIC DESIGN OF COLD-FORMED STEEL STRUCTURAL SYSTEMS WITH SUPPLEMENT 1**

**A. GENERAL**

This *Standard* provides the shear (lateral) capacity of seismic force-resisting systems appropriate for use in buildings and other structures framed from cold-formed steel structural members in seismic design. To develop the designated shear capacity and the overall response appropriate for the seismic performance factors associated with a given seismic force-resisting system, this *Standard* also provides the necessary detailing and design of the complete lateral force-resisting system, including the diaphragm.

In this first edition, the material represents a merging of AISI S110, *Standard for Seismic Design of Cold-Formed Steel Structural Systems—Special Bolted Moment Frames*, 2007 Edition with Supplement No. 1-09, and the seismic portions of AISI S213, *North American Standard for Cold-Formed Steel Framing—Lateral Design*, 2007 with Supplement No. 1-09. In addition, some of the seismic design requirements stipulated in this *Standard* are drawn from ANSI/AISC 341-10, *Seismic Provisions for Structural Steel Buildings*, developed by the American Institute of Steel Construction (AISC, 2010). The application of this *Standard* should be in conjunction with AISI S100, *North American Specification for the Design of Cold-Formed Steel Structural Members* (hereinafter referred to as AISI S100), and AISI S240, *North American Standard for Cold-Formed Steel Framing* (hereinafter referred to AISI S240).

**A1 Scope and Applicability**

**A1.1 Scope**

Buildings and other structures framed from cold-formed steel structural members may be designed using this *Standard* to design seismic force-resisting systems including the necessary detailing, connections and components, diaphragm design, and load transfer through the complete lateral force-resisting system appropriate for seismic design and seismic response factors selected from an appropriate load standard (as referenced from an applicable building code). Each seismic force-resisting system detailed in this *Standard* has a designated energy dissipating mechanism that is protected through detailing and provides a means to dissipate seismic energy at a level appropriate to that system. This *Standard* supplements the applicable building code, AISI S100 [CSA S136], and AISI S240.

**A1.2 Applicability**

This *Standard* is applicable for seismic design of buildings and other structures framed from cold-formed steel structural members. Conventional cold-formed steel construction has inherent overstrength and ductility that may be utilized in certain situations for seismic design. The *Standard* provides the specific case, detailed in this section (e.g. Seismic Design Category B or C and R = 3 in the United States), where the provisions of this *Standard* are not mandatory for seismic design.

This *Standard* is not applicable to cold-formed steel rack structures, which should be designed in accordance with the latest edition of *Design Testing and Utilization of Industrial Steel Storage Racks* by the Rack Manufacturers Institute (RMI). The RMI standard recognizes and provides design methodologies for the unique energy-dissipating mechanisms used in those
structures.

This Standard does not address the seismic design of cold-formed steel nonstructural members.

A1.2.3 The intent is for this Standard to govern whenever seismic detailing is required for a seismic force-resisting system. The only ASCE/SEI 7 cold-formed steel structural system permitted to exclude seismic detailing is the R=3 system in Line H of ASCE/SEI 7 Table 12.2.1—“Steel Systems Not Specifically Detailed for Seismic Resistance, Excluding Cantilever Column Systems” (ASCE, 2010). This system is permitted only in Seismic Design Category (SDC) B or C. This is similar to the approach that is currently taken for ANSI/AISC 341 (AISC, 2010). There are a number of systems that have a response modification coefficient less than three that have important seismic detailing requirements. For instance, if a gypsum board shear wall (R=2.5) is the designated seismic force-resisting system for a building, then it needs to meet the requirements found in AISI S400.

A2 Definitions

Codes and standards by their nature are technical, and 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 this Standard.

A2.1 Terms

In 2015, the term “boundary member” was revised to “boundary element” to be consistent with the definition in ASCE/SEI 7.

For multi-level buildings, boundary elements and chords should also include those at intermediate floor levels as the seismic forces in those floors need to be transferred to the vertical seismic force-resisting system.

Other terms defined in this section are self-explanatory.

A3 Materials

The ASTM steel designations and grades that are permitted by this Standard are based on those listed in AISI S100, AISI S240, and ANSI/AISC 341. In addition, ASTM A1085 was added. ASTM A1085 includes Grade 50 \([F_y = 50 \text{ ksi (345 MPa)}\) and \(F_t = 65 \text{ ksi (448 MPa)}\)]. In the Standard, some grades within designations are excluded to ensure a higher level of ductility and reserve strength for inelastic seismic loadings.

Grades excluded include A500 hollow structural sections Grades A and D; A572/A572M Grades 60 (415) and 65 (450); and Grades 70 (480) and 80 (550) of the various sheet specifications (A653/A653M, A875/A875M, A1008/A1008M, and A1011/A1011M). The remaining grades provide a \(F_u/F_y\) ratio not less than 1.15 and an elongation in 2 in. (50 mm) not less than 12 percent except for a few cases. The elongation is 11 and 9 percent for A1011/A1011M Grades 50 (340) and 55 (380), respectively, in thicknesses from 0.064 in. (2.5 mm) to 0.025 in. (0.65 mm). The elongation is 10 percent and the ratio 1.08 for all ST grades of A1003/A1003M.

In general, cold-formed steel structural members are formed from ASTM A1003/1003M (ASTM, 2011a) designated steel. As detailed in AISI S240, ASTM A1003/1003M provides minimum mechanical requirements. For seismic design, only ASTM A1003/1003M grades ST33H, ST37H, ST40H, and ST50H are applicable as they provide an elongation minimum (10 percent) and \(F_u/F_y\) ratio minimum (1.08) that are appropriate for this Standard.
A3.2 Expected Material Properties

Steel design is generally conducted with nominal properties; however, in seismic design it is often important to provide the best possible estimate of the expected (probable) properties. For example, if it is intended that one particular member yield, it is important to realize that this member will most probably yield at force levels significantly higher than those based on the nominal yield stress. This higher level is the expected [probable] property and is provided in this section through a series of modifiers ($R_y$, $R_t$, etc.) to the nominal mechanical properties.

A3.2.1 Material Expected Yield Stress [Probable Yield Stress]

The provided $R_y$ and $R_t$ values are based primarily on a database of typical properties of as-produced plate (Brockenbrough, 2003). The database included a significant quantity of relatively thin material (some supplied in coil form). The ratio of the mean yield stress to the specified minimum yield stress and the ratio of the mean tensile strength to the specified minimum tensile strength were as follows:

Table C-A3.2-1: Ratios of Mean-to-Specified Yield Stress and Mean-to-Specified Tensile Strength

<table>
<thead>
<tr>
<th>ASTM Designation</th>
<th>Thickness Range, in. (mm)</th>
<th>No. of Data Items</th>
<th>Ratio of Mean-to-Specified Yield Stress</th>
<th>Ratio of Mean-to-Specified Tensile Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>A36/A36M</td>
<td>0.188-0.75 (4.78-19.0)</td>
<td>14,900</td>
<td>1.30</td>
<td>1.17</td>
</tr>
<tr>
<td>A572/A772M Grade 50 (340)</td>
<td>0.188-0.50 (4.78-12.7)</td>
<td>1,161</td>
<td>1.17</td>
<td>1.18</td>
</tr>
<tr>
<td>A588/A588M</td>
<td>0.312-2.00 (7.70-50.8)</td>
<td>1,501</td>
<td>1.18</td>
<td>1.15</td>
</tr>
</tbody>
</table>

These values were generally supported by a subsequent study that included limited additional data and a review of existing data (Liu, et al., 2007). Rounded values were adopted for this Standard, which agree with those for plate material in ANSI/AISC 341. Although no data for the other plate steels listed in Table A3.2-1 of this Standard were available, it was considered likely that the ratios for ASTM A242/A242M, A283/A283M, and A529/A529M steel would be in the same range.

The $R_y$ and $R_t$ ratios for hollow structural sections for ASTM A500 Grades B and C steels were based on the data collected in 2015 by Judy Liu of Purdue University for the American Institute of Steel Construction (Liu, 2013), and these for ASTM A1085 steels were based on the data collected in 2015 by Kim Olson of FORSE Consulting for the Steel Tube Institute. The $R_y$ and $R_t$ ratios for all sheet and strip grades (ASTM A606, A653/A653M, A792/A792M, A875, A1003/A1003M, A1008/A1008M, and A1011/A1011M) were based on a 1995 study made by Bethlehem Steel for the U.S. Army Corps of Engineers on ASTM A653 (ASTM, 2002) material. In this study, data were gathered from two galvanized coating lines, where the conditions of the lines varied significantly so as to provide a good range of test results. However, the user is cautioned that while over 1000 coils were included in the study, individual sample size (grade/coating) varied from as few as 30 to as many as 717 coils. An individual sample may include several thicknesses for a given sample grade and coating.

This Standard allows $R_y$ and $R_t$ to be determined in accordance with an approved test.
method. Such a test method should prescribe a minimum of one tensile test per coil and not permit use of mill test reports. If a test value for \( R_y \) is available, the use of the test value is optional if less than the value in Table A3.2-1; however, the test value must be used if greater than the value in Table A3.2-1. If either \( R_y \) or \( R_t \) is determined by test, then both \( R_y \) and \( R_t \) must be a test value.

A3.2.2 Material Expected Tensile Strength [Probable Tensile Strength]

Determination of the expected [probable] tensile strength is detailed in the previous section.

A3.2.3 Material Modified Expected Yield Stress [Modified Probable Yield Stress]

For flexural members, the expected strength [probable resistance] may exceed the nominal strength [nominal resistance] due to factors beyond virgin steel mechanical properties (i.e., beyond \( R_y \) and \( R_t \)). The two most prominent are increased capacity due to cold work of forming in the corners of the cross-section, and increased capacity due to inelastic reserve in bending, i.e., \( R_{cf} \) and \( R_{re} \), respectively.

\( R_{cf} \), the factor to account for the increase in yield stress due to cold work of forming, may be determined by the provisions of AISI S100; alternatively, a minimum value of 1.10 may be used. This minimum is based on a review of typical cold-formed steel channel sections. An \( R_{cf} \) of 1.10 may be somewhat conservative for sections that are not fully effective, because the more limited effects of cold working are included indirectly in the basic strength equations for those sections.

\( R_{re} \), the factor to account for increased capacity due to inelastic bending, may be determined by the provisions of AISI S100. Although cold-formed steel sections are not commonly designed for capacity greater than first yield in bending (i.e., \( M_y \)), experiments and models show that for many sections, particularly those 0.097 in (2.4mm) and thicker, it is not at all uncommon. This consideration may be particularly important for the cold-formed steel Special Bolted Moment Frames and similar systems.

A3.3 Consumables for Welding

In addition to AWS, relevant commentary on consumables for welding may be found in ANSI/AISC 341 (AISC, 2010) Section A3.4, where applicable.

A4 Structural Design Drawings and Specifications

Seismic design requires more than typical coordination across multiple standards. To provide clarity, this Standard requires that specifications and design drawings clearly designate the seismic force-resisting systems selected from Chapter E along with the additional components and connections within a given seismic force-resisting system, as well as the components and connections between seismic force-resisting systems that allow the complete lateral force-resisting system to work. In addition to the provided requirements, relevant commentary on structural design drawing and specifications may be found in the AISI S202 (2015), and ANSI/AISC 341 (AISC, 2010) Section A4.1.

A5 Reference Documents

Seismic design requires significant coordination across standards and other documents. The documents listed here are the intended references based on the current version of this Standard.
B. GENERAL DESIGN REQUIREMENTS

Seismic design of buildings or other structures framed from cold-formed steel structural members consists of general seismic design requirements and the design of the lateral force-resisting system, which itself relies on a specific design basis detailed herein. The general seismic design requires consideration of the potential earthquake hazard, which is a function of location, occupancy, and building characteristics—most importantly mass, period, and damping. The general seismic design results in a required base shear capacity and a series of assumptions about the lateral force-resisting system that are embodied in the selected seismic response factors (e.g., R, C_d, and Ω_o in the United States, or R_d and R_o in Canada) and in the selected seismic force-resisting system.

This Standard provides the shear (lateral) capacity of a variety of cold-formed steel appropriate seismic force-resisting systems, and provides the necessary detailing for the selected systems to develop the inelastic and overstrength response assumed from the general seismic design from an applicable building code. Within each seismic force-resisting system, a specific energy-dissipating mechanism is designated. This mechanism must be protected for the seismic force-resisting system to behave as intended. Therefore, the expected strength of this mechanism must be determined, and all connections and components that are in the load path of this mechanism must be able to develop this load or the maximum load expected in the connection or component from the earthquake including overstrength. In addition, the complete lateral force-resisting system includes the selected seismic force-resisting systems, connections and components between these systems, and the diaphragm, all of which must be designed to ensure the energy-dissipating mechanisms in the seismic force-resisting systems are able to occur.

B1 General Seismic Design Requirements

B1.1 General

Any seismic design may follow this Standard, but it is presumed that the required strength [effects due to factored loads] of the lateral force-resisting system as a whole and the seismic force-resisting systems in specific are known from the general seismic design. Further, it is presumed that inelasticity and overstrength associated with the selected seismic force-resisting systems were considered when developing the required strengths [effects due to factored loads], as is the case in ASCE/SEI 7 and NBCC.

B1.2 Load Path

The engineer is responsible for detailing a complete and explicit load path for the lateral force-resisting system. This path should be envisioned from the collected forces at the base of the structure to all points of mass in the structure. Since most mass is carried by the floors, the load path should consider horizontal systems such as diaphragms, chords and collectors (drag struts) and details of the vertical system such as the seismic force-resisting system and connections and components between seismic force-resisting systems, as well as multi-floor and foundation connections and related components (e.g. hold-downs and anchorage).

B1.3 Deformation Compatibility of Members and Connections Not in the Seismic Force-Resisting System

Seismic force-resisting systems may result in larger lateral drifts than those in other common lateral designs such as wind. Once the design story drift is determined, depending on the
applicable building code, designated components and connections must be checked to determine if they can accommodate the drift. This is an important consideration, as secondary components or other unintended (potentially brittle) load paths may be engaged if deformations are not accommodated. For additional relevant commentary on deformation compatibility of members and connections not in the seismic force-resisting system, see ANSI/AISC 341 (AISC, 2010) Commentary Section D3.

**B1.4 Seismic Load Effects Contributed by Masonry and Concrete Walls**

The use of cold-formed steel seismic force-resisting systems with masonry or concrete walls is common practice. However, due to significant differences in stiffness and response, care must be taken. Specific details are provided for each vertical seismic force-resisting system in Chapter E and for the diaphragm in Chapter F.

The Chapter E requirements are patterned after provisions in the Special Design Provisions for Wind and Seismic (AFPA, 2005b) and were adopted in a precursor to this Standard in 2007 (AISI S213-07). As detailed in Chapter E, when the cold-formed steel seismic force-resisting systems resist seismic forces contributed by masonry and concrete walls, deflections are limited to 0.7% of the story height at LRFD design load [factored load] levels in accordance with deflection limits for masonry and concrete construction and Section 12.8.6 of ASCE/SEI 7 (ASCE, 2010). The intent is to limit failure of the masonry or concrete portions of the structure due to excessive deflection.

As detailed in Chapter F, wood structural panel sheathed diaphragms are not permitted where forces contributed by masonry or concrete walls result in torsional force distribution through the diaphragm. A torsional force distribution through the diaphragm would occur when the center of rigidity is not coincident with the center of mass, such as in an open front structure, a condition which is prohibited in Chapter F.

It should also be noted that Section 12.10.2.1 of ASCE/SEI 7 (ASCE, 2010) requires that collectors, splices, and their connections to resisting components be designed for the amplified seismic load when a structure is not braced entirely by light-frame shear walls. This imposes an additional requirement for collectors when cold-formed steel framing is used to resist seismic forces contributed by masonry and concrete walls.

**B1.5 Seismic Load Effects From Other Concrete or Masonry Components**

Seismic forces from other concrete or masonry construction (i.e., other than walls) are permitted and should be accounted for in design. The provisions of this section specifically allow masonry veneers; i.e., a masonry facing attached to a wall for the purpose of providing ornamentation, protection or insulation, but not counted as adding strength to the wall. Likewise, the provisions of this section are not intended to restrict the use of concrete floors—including cold-formed steel framed floors with concrete toppings as well as reinforced concrete slabs— or similar components in floor construction. It is intended that where such components are present in combination with a cold-formed steel framed system, the cold-formed steel framed system needs to be designed to account for the seismic forces generated by the additional mass of such components. The design of cold-formed steel members to support the additional mass of concrete and masonry components needs to be in accordance with AISI S100 [CSA S136] and required deflection limits as specified in concrete or masonry standards or the model building codes.
B2 Lateral Force-Resisting System

The objective of the seismic design is to provide a lateral force-resisting system that has the available base shear capacity (available strength) to meet the required base shear demands (required strength) and is detailed in such a manner to provide the ductility and overstrength assumed in the applicable building code.

B3 Design Basis

At its simplest level, this Standard provides the available strength [factored resistance] (base shear capacity) for several different seismic force-resisting systems that may be summed to determine the total available strength [factored resistance] and then compared against the required strength [effect due to factored loads] (base shear demand) from the applicable building code. The available strength [factored resistance] is determined from the nominal strength [nominal resistance] using resistance or safety factors as appropriate.

To achieve the desired ductility and overstrength, the design basis is slightly more complicated. Each seismic force-resisting system has within it a designated energy-dissipating mechanism. This mechanism must be engaged, and other limit states avoided, in the seismic force-resisting system for the energy dissipation to occur as intended. To ensure this, the engineer determines the expected [probable] strength of the energy-dissipating mechanism, and all other connections and components in the seismic force-resisting system must develop this strength without failure. Thus, the expected strength [probable resistance] of the designated energy-dissipating mechanism becomes one possible required strength [effect due to factored loads] for all connections and components in the seismic force-resisting system that are not part of the designated energy-dissipating mechanism.

In the United States and Mexico: A second possibility is recognized–connections and components outside of the energy-dissipating mechanism do not need to be designed for required strengths higher than the seismic load effect including overstrength (Ωo).

In Canada: A different second possibility is recognized–Effects due to factored loads for connections and components outside of the energy-dissipating mechanism do not have to be greater than elastic seismic load effects (i.e. RdRo=1.0).

B3.3 Expected Strength [Probable Resistance]

The expected strength [probable resistance] may be expressed as a factor (ΩE) times the nominal strength.

In the United States and Mexico: In AISI S400-15 an upperbound (conservative) value for ΩE = Ωo was employed when additional information for determining ΩE was unavailable, e.g., in Section E1.3.3. In 2016, a more precise upperbound estimate for ΩE was recognized. At the design limit, ϕVn=Vbe/R where Vbe is the elastic base shear demand. The expected equilibrium between the demand and capacity is ΩoVbe/R = Vn + Vo where Vo is the lateral resistance of elements outside of the seismic force-resisting system (SFRS). Substituting the design limit for Vn and assuming, as an upperbound, that no force is carried outside of the SFRS (Vo = 0) results in an upperbound estimate of ΩE = ϕΩo. This upperbound would appear to reward systems with low ϕ (i.e. highly variable). As an additional check, it is considered that the exceedance probability of the upperbound capacity (ΩEVn) should be the same as the lowerbound failure probability, assuming a symmetrical probability distribution.
This implies: \( \Omega = V_n + (V_n - \phi V_n) \), or \( \Omega = 2 - \phi \). Thus, an upperbound is established that \( \Omega = \max(\phi \Omega, 2 - \phi) \). This upperbound is applied in this Standard when additional information is unavailable for determination of \( \Omega_E \).
C. ANALYSIS

C1 Seismic Load Effects

The analysis of cold-formed steel systems for seismic response can be complicated due to connection flexibility, member cross-section deformations, and significant nonlinearities in hysteretic response of typical connections, components, and assemblies (e.g., shear walls). As a result, typical analysis models are heavily simplified and equivalent lateral force methods detailed in applicable building codes are almost exclusively used. Research is ongoing to extend current analysis capabilities and provide reliable nonlinear time history analysis results in the future. Guidance on the use of these methods will be provided in future versions of this Standard.

D. GENERAL MEMBER AND CONNECTION DESIGN REQUIREMENTS

No additional requirements regarding member and connections are provided in this chapter.
E. SEISMIC FORCE-RESISTING SYSTEMS

Design requirements for seismic force-resisting systems defined in the applicable building code in the United States and Mexico: ASCE/SEI 7-10 (ASCE, 2010) and in Canada: NBCC (NRCC, 2010), are provided in this section of the Standard. The seismic performance factors, e.g., the seismic response modification coefficient, $R$, overstrength factor, $\Omega_0$, and deflection amplification factor, $C_d$, provided by the applicable building code are applicable if the seismic detailing of the associated seismic force-resisting system meets the seismic design requirements of this Standard.

Seismic design consists of several main steps:

1. Proportioning and detailing of the designated energy-dissipating mechanism in the seismic force-resisting system (e.g., diagonal strap bracing in strap braced wall systems). Specifically, the nominal strength [resistance] of the seismic force-resisting system is determined, then modified to provide the available strength [factored resistance], which must be greater than the required strength [effect due to factored loads] from the seismic load combination;

2. Ensuring ductility, proportioning and detailing of other parts of the seismic force-resisting system (e.g., chord studs, hold-downs and anchorage in strap braced wall systems) for a required strength [effect due to factored loads] equal to the expected strength [probable resistance] developed by the designated energy-dissipating mechanism; and

3. Ensuring a complete load path and system, proportioning and detailing of any other components and connections of the lateral force-resisting system (e.g., diaphragms, collector, and chords), which are in the path of the inertial loads developed by the effective seismic masses of the building and transmitted to the foundation or supporting structural components.

To provide consistency with the outlined seismic design method, the nominal strength [resistance] of the seismic force-resisting systems in this Standard are based on total shear (lateral) strength and not the strength per unit length, as previously provided in AISI S213 (AISI, 2007b). For all seismic force-resisting systems defined in this chapter of the Standard, a similar design procedure is provided to ensure fulfillment of the seismic design requirement.

### E1 Cold-Formed Steel Light Frame Shear Walls Sheathed With Wood Structural Panels

Cold-formed steel framed shear walls sheathed with wood structural panels are a commonly used seismic force-resisting system and provide sufficient lateral shear strength and ductility if properly designed and detailed. This section provides provisions to meet these requirements.

#### E1.1 Scope

Provisions for cold-formed steel framed shear walls sheathed with wood structural panels are applicable in the United States, Mexico, and Canada.

#### E1.2 Basis of Design

##### E1.2.1 Designated Energy-Dissipating Mechanism

Energy-dissipating mechanisms are determined primarily based on test observations and experimental results. Identifying the energy-dissipating mechanism in a seismic force-resisting system requires substantial knowledge and places important additional requirements on the design of other components and connections in the seismic force-resisting system; e.g., the
chord studs. Cold-formed steel framed shear walls sheathed with wood structural panels experience productive energy dissipation as the connector between the stud and sheathing undergoes tilting and bearing against the wood structural panel.

**E1.2.2 Seismic Design Parameters [Seismic Force Modification Factors and Limitations] for Seismic Force-Resisting System**

In the United States and Mexico: When the seismic response modification coefficient, $R$, is not equal to 3, the design must follow the seismic requirements of this Standard. When $R$ is equal to 3, the design may follow the requirements of AISI S240 or this Standard. Use of AISI S400 requires an applicable building code and referenced load standard. For ASCE/SEI 7 (ASCE, 2010), the design coefficients, factors and limitations assigned to light-framed shear wall systems are reproduced in Table C-E1.2.2. ASCE/SEI 7 also provides limitations based on the Seismic Design Category. For Seismic Design Category A through C, the designer has the option to use an $R = 3$ for systems with a higher assigned $R$ when determining the seismic load. When this is done, the provisions of AISI S240 may be followed and the special detailing in accordance with this Standard avoided. For this case, the design coefficients and factors for "Steel Systems Not Specifically Detailed for Seismic Resistance Excluding Cantilever Column Systems" of ASCE/SEI 7 (2010) apply. In Seismic Design Category D through F, the designer does not have the option to choose an $R = 3$ for systems with a higher assigned $R$. The design coefficients and factors in Table C-E1.2.2 apply and the provisions of this Standard are mandatory. Note, it is never permitted to choose $R = 3$ for systems with a lower assigned $R$.

In Canada: When $R_dR_o$ is not equal to 2 for sheathed shear walls, this Standard is applicable. When $R_dR_o$ is equal to 2 for sheathed shear walls, the AISI S240 standard is adequate. For sheathed shear walls, a designer has the option to choose an $R_dR_o$ of 2 for systems with a higher $R_dR_o$ to determine the seismic load and thereby avoid the special detailing in this Standard. For this case, the height limitations for “Other Cold-Formed Steel Seismic Force-Resisting System(s)” in Table 1.2-1 in Appendix 1 of this Standard apply.
Table C-E1.2.2d
United States and Mexico
Design Coefficients and Factors for Shear Walls Sheathed With Wood Structural Panels

<table>
<thead>
<tr>
<th>Basic Seismic Force-Resisting System (^b)</th>
<th>Seismic Response Modification Coefficient, (R)</th>
<th>System Overstrength Factor, (\Omega_o)(^c)</th>
<th>Deflection Amplification Factor, (C_d)</th>
<th>Structural System Limitations and Building Height (ft) Limitations (^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. BEARING WALL SYSTEMS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light-framed walls sheathed with wood structural panels rated for shear resistance</td>
<td>6½</td>
<td>3</td>
<td>4</td>
<td>NL</td>
</tr>
<tr>
<td>Light-framed walls sheathed with wood structural panels rated for shear resistance</td>
<td></td>
<td></td>
<td></td>
<td>NL</td>
</tr>
<tr>
<td>B. BUILDING FRAME SYSTEMS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light-framed walls sheathed with wood structural panels rated for shear resistance</td>
<td>7</td>
<td>2½</td>
<td>4½</td>
<td>NL</td>
</tr>
<tr>
<td>Light-framed walls sheathed with wood structural panels rated for shear resistance</td>
<td></td>
<td></td>
<td></td>
<td>NL</td>
</tr>
</tbody>
</table>

\(^a\) NL = Not Limited and NP = Not Permitted.

\(^b\) Per ASCE/SEI 7 (ASCE, 2010), a bearing wall system is defined as a structural system with bearing walls providing support for all or major portions of the vertical loads, and a building frame system is defined as a structural system with an essentially complete space frame providing support for vertical loads. Per this Standard, shear walls are the basic seismic force-resisting elements.

\(^c\) The tabulated value of the overstrength factor, \(\Omega_o\), is permitted to be reduced by subtracting one-half for structures with flexible diaphragms, but shall not be taken as less than 2.0 for any structure.

\(^d\) See ASCE/SEI 7 (ASCE, 2010) Table 12.2-1 for additional footnotes.

For SI: 1 ft = 0.305 m

**E1.2.3 Type I or Type II Shear Walls**

*Type I shear walls* are fully sheathed with *wood structural panels* and with *hold-downs* and anchorage at each end. For example, Figure C-E1.2.3-1(a) is an example of a wall with two *Type I shear walls*. This form of detailing is the most common for *Type I shear walls*. *Type I shear walls* are permitted to have openings when details are provided to account for force transfer around the openings, as depicted in C-E1.2.3-1(b). See additional commentary in AISI S240.

*Type II shear walls* sheathed with *wood structural panels* are permitted to have openings between the ends (*chord studs* with *hold-downs* and anchorage); however, the width of such openings should not be included in the length of the *Type II shear wall* and the openings do not have to be detailed for force transfer, as depicted in Figure C-E1.2.3-2.
Figure C-E1.2.3-1(a) – Type I Shear Walls Without Detailing for Force Transfer Around Openings

Figure C-E1.2.3-1(b) – Type I Shear Wall With Detailing for Force Transfer Around Openings

Figure C-E1.2.3-2 – Typical Type II Shear Wall
E1.2.4 Seismic Load Effects Contributed by Masonry and Concrete Walls

For general commentary on seismic load effects contributed by masonry and concrete walls, see Section B1.4.

E1.3 Shear Strength [Resistance]

E1.3.1 Nominal Strength [Resistance]

E1.3.1.1 Type I Shear Walls

The nominal strength [resistance] of the wall in shear is determined by multiplying the length of the wall by the tested wall capacity per length of wall. For narrow walls with aspect ratios greater than 2 and less than or equal to 4, an additional reduction is applied consistent with test observations for narrow aspect ratio walls (Serrette, 1997). The tested shear wall capacity is based on an estimate of degraded strength under cyclic shear wall tests. Details of this estimate are different for the United States (and Mexico) and Canada. Since the tabulated values in this 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 this Standard, as discussed in Section A.

In the United States and Mexico: Shear wall tests were conducted to the Sequential Phase Displacement (SPD) protocol and strength was determined from a degraded (secondary) cycle of the wall strength envelope. The initial tests were conducted by Serrette (1996, 1997 and 2002) and included reverse cyclic and monotonic loading for plywood, oriented strand board, and gypsum wall-board shear wall assemblies. The basic reversed cyclic test protocol used is illustrated in Figure C-E1.3.1-1, and is known as the Sequential Phase Displacement or (SPD) protocol. Typical hysteretic response and typical peak and degraded strength envelopes are illustrated in Figure C-E1.3.1-2. The degraded wall strength is the set of points describing the peak strength associated with the second cyclic of a target (repeated) input displacement. Nominal strength of a tested wall was defined as the smaller one of the maximum strength and 2.5 times the strength at 0.5 in. of lateral displacement. The 0.5 in. displacement was based on the allowable strength drift limit for an 8-ft wall in accordance with the 1994 Uniform Building Code (ICBO, 1994), which was the code in effect at the time this information was first proposed for acceptance in a building code. Typically, the degraded maximum strength controlled.
In Canada: Shear wall tests were conducted to the CUREE protocol and strength was determined from an equivalent energy elastic–plastic (EEEP) analysis of the cyclic wall strength envelope curve. The test program of single-story laterally loaded shear walls constructed of Canadian sheathing products was initiated by Branston et al. (2006b). Based on the data obtained from this test program, as well as the wall behavior/performance that was observed (Chen et al., 2006), a design method was developed (Branston, 2006a). Shear resistance values for additional wall configurations have been provided by Boudreault (2005), Blais (2006), Rokas (2006) and Hikita (2006). Monotonic testing (Figure C-E1.3.1-3(a)) was carried out, along with reversed cyclic testing, in which the CUREE protocol for ordinary ground motions (Figure C-E1.3.1-4) (Krawinkler et al., 2000; ASTM E2126 2005) was used for the majority of wall specimens (Boudreault, 2005). A typical shear resistance vs. displacement hysteresis for a reversed cyclic test is provided in Figure C-E1.3.1-3(b). Nominal resistance values for wood sheathed shear walls were obtained from the test data using the equivalent energy elastic–plastic (EEEP) analysis approach (Figure C-E1.3.1-5). The concept of equivalent energy was first proposed by Park (1989) and then presented in a modified form by Foliente (1996). A codified version of the equivalent energy elastic–plastic (EEEP) approach to calculating the design parameters of light-framed shear walls can also be found in ASTM E2126 (2005).
In Canada: In the case of each reversed cyclic test, a backbone curve was first constructed for both the positive and negative displacement ranges of the resistance vs.
deflection hysteresis. This backbone curve represents the outer envelope of the first loading cycles in the CUREE protocol. The resistance vs. deflection curve for monotonic specimens and the backbone curves for cyclic tests were used to create EEEP curves based on the equivalent energy approach, as illustrated in Figure C-E1.3.1-6. The resulting plastic portion of the bilinear curve was defined as the nominal resistance. The 2005 NBCC also requires that for seismic design, lateral inelastic deflections be limited to 2.5% of the story height for buildings of normal importance. A limit of 2.5% drift was also used in the energy balance (Branston et al., 2006b). When this inelastic drift limit was incorporated, it had the effect of lowering the recommended nominal resistance. A typical series of tests (monotonic and backbone) and EEEP curves for a wall configuration is shown in Figure C-E1.3.1-7. Since the CUREE reversed cyclic protocol for ordinary ground motions produces results that are very similar to those revealed by a monotonic test for an identical wall configuration (Chen, 2004; Chen et al., 2006), it was decided that the results for the monotonic tests and the reversed cyclic tests would be combined to produce a minimum of six nominal shear values for each wall configuration. The recommended nominal resistance of the steel frame/wood panel shear walls was initially developed based on the mean value of the monotonic and reversed cyclic test data for a particular wall configuration. A reduction factor was then determined from the assumed normal statistical distribution of test-to-predicted (mean) results, which made it possible to recommend the fifth percentile results that are tabulated in the Standard. Use of the fifth percentile approach to determine nominal shear strengths resulted in an average ASD safety factor of 2.67 (Branston et al., 2006a).

Figure C-E1.3.1-6 – Typical Test and EEEP Curves: (a) Monotonic; (b) Reversed Cyclic
Since the shear wall tests were carried out over a short time span, the tabulated values are for short-term duration loads, including earthquake (and wind). In general, wood products exhibit a decreased resistance to long-term loads, and hence the shear resistance should be decreased accordingly for standard and permanent loads. In the United States and Mexico, it is recommended to follow NDS, e.g., the 2015 NDS (AFPA, 2015); and in Canada, CSA O86 (CSA, 2001).

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/SEI 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 (Serrette, 2006).

All provided shear wall capacities are based on testing. System requirements consistent with the conducted testing are detailed in Section E1.4 and flagged in the notes of the shear capacity Table E1.3-1. Due to the prescriptive nature of the tabulated shear values, care must be taken to follow the complete requirements to ensure the designated energy-dissipating mechanism is initiated in the system.

**E1.3.1.1 Wall Pier Limitations**

The requirement for the minimum length of a wall pier is considered consistent with the available test data and maximum $h_p/w_p$ criterion ($h_p/w_p \leq 2$). For a typical story height of 8 ft (2440 mm) and about 50% full-height sheathing, the minimum
allowable length of the wall is 24 inches (610 mm), which is a typical distance used to place studs. The structural behavior of narrow wall piers can induce significant bending in the chord studs and other changes that result in limit states not anticipated in this Standard. Further, narrow wall piers may provide a reduced lateral stiffness that leads to deformation incompatibilities, and at a minimum more rigorous analysis of the wall to understand force transfer would be required.

**E1.3.1.1.2 Both Wall Faces Sheathed With the Same Material and Fastener Spacing**

Per Section E1.2.1 of the Standard, connections between the wood structural panel sheathing and the cold-formed steel structural members are the primary energy-dissipating mechanism in sheathed shear walls. Employing the same material and fastener spacing on both faces of the wall doubles the number of fasteners and accordingly the nominal strength [resistance] of the wall in the seismic force-resisting system. However, increasing the nominal strength [resistance] increases the expected strength [probable resistance] of the shear wall developed by the designated energy-dissipating mechanism. Accordingly, other components of the seismic force-resisting system, i.e., chord studs, hold-downs and anchorage, should be able to carry the applied load determined based on the expected strength [probable resistance] of the shear wall.

**E1.3.1.1.3 More Than a Single Sheathing Material or Fastener Configuration**

While no extensive experimental results are available to provide a definitive nominal strength [resistance] for different combinations of material sheathing, a conservative limit state design method is adopted as follows.

Different types of shear wall sheathing and fastener spacing can provide different nonlinear behavior and nonlinear deformation capacity for shear walls. While both sides of the wall will experience the same lateral deformation demand, superimposing nominal strength [resistance] provided by each individual face is not valid. Accordingly, a limit state method is provided in this Standard to account for different sheathings and fastener spacing of the shear wall faces. Correspondingly, two scenarios are considered. In the first scenario, the weaker material fails first while the stronger is still working. In this case it is reasonable to assume the stronger side can at least provide a capacity equal to the weaker part, and the total shear wall capacity can be determined assuming the weaker (lower nominal strength [resistance]) material or fastener configuration exists for the whole wall. In the other scenario, the weaker side of the wall fails earlier and the stronger side carries over the redistributed load until failure. If the failure load of the stronger side is larger than the capacity determined in the first scenario, this failure load can be taken as the shear wall capacity. Otherwise, the shear capacity of the wall will be the capacity determined based on the assumption that the weaker material is on both sides of the wall.

Although the provided solution is conservative from a nominal strength [resistance] standpoint, it may not be conservative to utilize this method in calculating expected strength [probable resistance] of the shear wall. Based on engineering judgment, the sum of the strength of the two dissimilar wall sheathing materials or fastener spacings is a reasonable upperbound estimate. This summed strength should be converted to expected strength based on observed bias, or in the absence of data, in the United States and Mexico using $\Omega_o$, and in Canada using elastic ($R_dR_o=1$) force
levels.

Using multiple layers of sheathing on one side of the shear wall can substantially change the failure mode of the sheathing connectors. However, this effect has not been studied extensively to date. Accounting for only the innermost layer when determining the strength is assumed to be conservative.

### E1.3.1.2 Type II Shear Walls

The requirements for Type II shear walls, also known as perforated shear walls, in Section E1.2.3 are 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:

\[
F = \frac{r}{3 - 2r} \tag{Eq. C-E1.3.1.2-1}
\]

where

\[
r = \frac{1}{1 + \frac{A_0}{h} \sum L_i} \tag{Eq. C-E1.3.1.2-2}
\]

- \( A_0 \) = 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-framed 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 E1.3.1.2-1 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). There is also a similar table in AISI S230 (AISI, 2012b); however, AISI S230 establishes an adjustment factor for the shear wall length rather than the shear wall resistance.

In accordance with Standard Section E1.3.1.1, it is required to check the aspect ratio \((h/w)\) 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, \( C_a \).

### E1.3.2 Available Strength [Factored Resistance]

AISI S100 provides a summary of the first order reliability method used for determining limit states-based safety (\( \Omega \)) and resistance (\( \phi \)) factors. In the United States and Mexico: The shear wall safety factor (\( \Omega \)) was based on successful past practice with
diaphragms and engineering judgment. Conversion from $\Omega$ to $\phi$ was based on expressions provided in Chapter F of AISI S100 (AISI, 2012). The safety and resistance factors for steel sheathed shear walls were developed based on the research by Yu (2007). In Canada: A resistance factor ($\phi$) was calibrated according to the LSD (Limit States Design) procedures prescribed in the 2005 NBCC (the procedure is nearly identical to AISI S100 Chapter F). A reliability index, $\beta_o$, of 2.5 was used because the recommended nominal design resistances are not the ultimate capacity of the test walls (Fig. C-E1.3.1-6). A $\phi$ of 0.7 was obtained for 2005 NBCC wind forces, and it is recommended that the same $\phi$ be used in seismic design. This value was used by Boudreault et al. (2007) in the calculation of $R_o$. The resistance factor for steel sheathed shear walls was developed by Balh et al. (2014) and DaBreo et al. (2014).

**E1.3.3 Expected Strength [Probable Resistance]**

This Standard incorporates a capacity-based design approach in which an element (fuse) of the seismic force-resisting system of a structure is designed to dissipate energy. The fuse element, known as the designated energy-dissipating mechanism, must be able to carry seismic loads over extensive inelastic displacements without sudden failure. It is expected that the fuse element will fail in a ductile, stable and predictable manner, at which time it will reach and maintain its maximum load-carrying resistance. In a structure that makes use of cold-formed steel framed shear walls with wood structural panels as lateral force-resisting elements, the shear walls themselves can initially be thought of as the fuse elements in the larger lateral force-resisting system. More specifically, it is the sheathing-to-steel framing connections of the shear wall that have been shown to fail in a ductile fashion and hence, it is these connections that are the designated energy-dissipating mechanism – i.e., the fuse. Thus, we seek the expected strength of this mechanism so that it can be protected.

The capacity-based design approach stipulates that all other components and connections in the lateral load-carrying path must be designed to withstand the expected [probable] strength of the designated energy-dissipating mechanism (fuse) element, where the expected strength takes into account expected overstrength (strength above nominal) that may exist. In the case of a cold-formed steel framed shear wall, the system includes the chord studs, field studs, hold-down and anchorage, track, etc.; these components are designed to carry the expected [probable] strength of the shear wall while the sheathing-to-framing connections fail in a ductile manner. To design the chord studs and other components of the seismic force-resisting system, it is necessary to estimate the probable capacity of the shear wall based on a sheathing connection failure mode. This can be achieved by applying an overstrength factor to the nominal resistance (Figure C-E1.3.3-1).

In the United States and Mexico: It should be noted that the nominal strengths shown in Table E1.3-1 are based on a degraded backbone curve determined using the SPD cyclic protocol (Figure C-E1.3.1-1). Testing of similar specimens with the SPD and CUREE cyclic protocol were 20 percent higher using the CUREE cyclic protocol (Boudreault, 2005). Thus, expected strengths in the United States and Mexico are at least 1.2 times $v_n$ in Table E1.3-1. However, no additional analysis has been conducted for finding expected strength. As a result, the upperbound estimate introduced in Commentary Section B3.3 is employed: $\Omega_E = \max(\phi \Omega_o, 2 - \phi)$. For this system, $\phi = 0.6$, and based on ASCE/SEI 7-10, $\Omega_o = 3$ for bearing wall systems and 2.5 for building frame systems, resulting in $\Omega_E = 1.8$.

In Canada: Comparison of the ultimate test shear resistance with the recommended fifth percentile nominal design resistance provided justification for an overstrength factor
of 1.33 for walls sheathed with DFP and OSB, and 1.45 for walls sheathed with CSP panels. Initial selection of the shear wall to resist the expected NBCC seismic base shear should be based on a factored resistance; i.e., the overstrength factor should not be included during wall selection. The probable capacity is only used to estimate the forces in the design of the non-fuse elements of the seismic force-resisting system.

Investigations into the effect of combined gravity and lateral loads on shear wall performance by Hikita (2006) have shown that the addition of gravity loads does not change the lateral performance characteristics of a steel frame/wood panel shear wall if the selection of the chord studs is appropriate; i.e., the chord studs are designed to resist the compression forces due to gravity loads in combination with the forces associated with the expected [probable] ultimate shear strength [capacity] of the wall as controlled by sheathing connection failure.

E1.4 System Requirements

The system requirements detailed in Section E1.4 are necessary for the seismic force-resisting system to develop the desired strength and ductility, as demonstrated through testing. The provisions are a combination of prescriptive recreations of the physically tested specimens and engineering judgment with respect to potential and practical substitutions. Wherever possible, this Standard has tried to provide appropriate minimum (or maximum) conditions instead of direct prescriptions. An engineer should be aware that if they deviate significantly from suggested values, behavior may diverge from the desired as well.

E1.4.1 Type I Shear Walls

E1.4.1.1 Limitations for Tabulated Systems

Limitations (a) to (r) should be met for systems utilizing the tabulated shear capacity of Table E1.3-1. Substitutions are subject to the provisions of Chapter H or more generally the rational analysis clause of Chapter A (Section A1.2.5).

It is important to note that Table E1.3-1 designates the chord stud thickness and minimum fastener size. Per Note 5 of Table E1.3-1, thicker studs are not allowed unless specified in the table – this is to avoid screw shear limit states that become common when thicker stud materials are employed.
Overdriving of the sheathing screws will result in reduced performance 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. 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.

E1.4.1.2 Required Strength [Effect Due to Factored Loads] for Chord Studs, Anchorage, and Collectors

In the United States and Mexico: Section 12.10.2.1 of ASCE/SEI 7 (ASCE, 2010) exempts structures or portions thereof that are braced entirely by light-frame shear walls from the requirement to have collectors, splices, and connections to resisting components designed to resist amplified seismic loads. Nevertheless, to develop a desirable response, this Standard requires that connections for boundary elements transferring load to and from the shear wall be capable of developing the expected [probable] strength of the shear wall. In the U.S. and Mexico, this includes collectors, chord studs or other vertical boundary elements, hold-downs and anchorage connected thereto, sill plate shear anchors, and all other components and connections of the shear wall that are not part of the designated energy-dissipating mechanism. Diaphragms are not required to be designed for the shear wall expected strength. The expected [probable] strength for shear walls with wood structural panels is, as of 2014, estimated as the nominal strength [resistance] amplified by the system overstrength factor, $\Omega_o$; thus, this Standard does require amplified seismic loads to be considered for these components. This requirement is applicable to splices in track that serves as a boundary element.

E1.4.1.3 Required Strength [Effect Due to Factored Loads] for Foundations

In the United States and Mexico: Foundation design does not strictly follow a capacity-based design methodology. Per ASCE/SEI 7 (ASCE, 2010), requirements for detached one- and two-family dwellings of light-frame construction not exceeding two stories above grade plane assigned to Seismic Design Category D, E, or F are modified and need only comply with the requirements for ASCE/SEI 7-10 Sections 11.8.2, 11.8.3 (Items 2 through 4), 12.13.2, and 12.13.5.

E1.4.1.4 Design Deflection

The deflection provisions are based on work performed by Serrette and Chau (2003). Equation E1.4.1.4-1 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 [resistance] 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 element contribution), linear elastic sheathing shear, a contribution for overall nonlinear effects and a lateral contribution from hold-down and anchorage deformation. These four contributions are additive.
Linear elastic cantilever bending: \( \frac{2v^2h^3}{3E_sA_c b} \) (Eq. C-E1.4.1.4-2)

Linear elastic sheathing shear: \( \frac{v}{\rho G_{t, \text{sheathing}}} \) (Eq. C-E1.4.1.4-3)

Overall nonlinear effects: \( \frac{\omega_1^{5/4}}{\rho_0^{\omega_2/\omega_3^2}} \cdot \left( \frac{v}{\beta} \right)^2 \) (Eq. C-E1.4.1.4-4)

Lateral contribution from hold-down and anchorage deformation: \( \frac{h}{b} \delta_v \) (Eq. C-E1.4.1.4-5)

The lateral contribution from hold-down and anchorage deformation is dependent on the aspect ratio of the wall, as illustrated in Figure C-E1.4.1.4-1. 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. The equations were based on Type I shear walls without openings, and the user should use with caution if applying them to Type I shear walls with openings. The shear wall deflection equations do not account for additional deflections that may result from 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 \( (G_v t_v) \), the nominal panel thickness \( (t) \) and through-thickness panel grade and construction adjustment factor \( (C_G) \) provided in the Manual for Engineered Wood Construction (AFPA, 2001). For example, \( G \) for 7/16-in. 24/16 OSB rated sheathing can be approximated as follows:
G_v t_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_C = 3.1
G (approximate) = 3.1 x 25,000 / 0.437 = 177,300 psi
Thus, C_C G_v t_v = 77,500 lb/inch and G_t = 77,500 lb/inch

A comparison of the C_C G_v t_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.

In 2009, Standard Equation E1.4.1.4-1 for determining the deflection of a blocked wood structural panel was consolidated for U.S. Customary and SI Units in AISI S213, a precursor to this Standard.

In 2012, in AISI S213, coefficients β and ρ in deflection Equation C-E1.4.1.4-1 were revised for Canadian Soft Plywood (CSP), based on research results compiled by Cobeen (2010). CSP was differentiated from other plywoods based on the performance of that material. Note that Canadian Douglas Fir Plywood (DFP) was found to behave similarly to plywood in common use in the United States.

E1.4.2 Type II Shear Walls

E1.4.2.1 Additional Limitations

Type II shear walls must meet all the requirements of Type I shear walls and the additional requirements provided in this section. If the Type II shear wall has non-uniform height or other complexities, the simplified approach provided in this Standard may not be adequate. See Dolan (1999, 2000a, 2000b) for more information.

E1.4.2.2 Required Strength [Effect Due to Factored Loads] for Chord Studs, Anchorage, and Collectors

Design of chord studs, anchorage and collectors for Type II shear walls follows the same philosophy as Type I shear walls. See the commentary for Section E1.4.1.2.

E1.4.2.2.1 Collectors Connecting In-Plane Type II Shear Wall Segments

Type II shear wall segments are designed as Type I shear walls, and thus the designated energy-dissipating mechanism is within the Type II shear wall segment. Therefore, collectors connecting in-plane Type II shear wall segments must be designed for the expected [probable] strength of the segments to protect the designated energy-dissipating mechanism.

E1.4.2.2.2 Uplift Anchorage and Boundary Chord Forces at Type II Shear Wall Ends

Uplift anchorage (hold-downs and anchorage) and chord studs are outside of the designated energy-dissipating mechanism and thus should be designed for the expected [probable] strength of the designated energy-dissipating mechanism to ensure ductility in the seismic force-resisting system.

E1.4.2.2.3 Uplift Anchorage Between Type II Shear Wall Ends

The Standard requires that equilibrium be maintained between anchorage and collectors between Type II shear wall segments; therefore, the collected shear in these
segments must also be accounted for in the anchorage design of the same segments.

**E1.4.2.3 Design Deflection**

Prescriptive equations for the deflection of Type II shear walls are not provided in the Standard. Care should be taken if attempts are made to extend the method of Section E1.4.1.4. The largest contribution to deflection in the Section E1.4.1.4 method is the empirical nonlinear “$\rho$” term and the modification of this value for Type II shear wall segments is unknown. In addition, actual deflections include friction, bearing, slip, and a variety of mechanisms that are difficult to account for without at least partial experimental calibration.
E2 Cold-Formed Steel Light Frame Shear Walls With Steel Sheet Sheathing

Cold-formed steel framed shear walls with steel sheet sheathing can provide adequate lateral shear strength and ductility if properly designed and detailed. This section provides provisions to meet these requirements. The organization is identical to shear walls with wood structural panels as presented in the Standard and Commentary of Section E1. This section largely parallels the Section E1 presentation, and the engineer is recommended to read the full Section E1 commentary in addition to this section.

E2.2 Basis of Design

E2.2.1 Designated Energy-Dissipating Mechanism

Ductility in steel sheet shear walls results from bearing deformations at the stud-to-steel sheet connections and yielding in the tension fields that develop across the steel sheet between and perpendicular to buckled portions of the steel sheet(s). Thickness and yield stress of the sheet are critical for this mechanism and both are prescribed in the Standard.

E2.2.2 Seismic Design Parameters [Seismic Force Modification Factors and Limitations] for Seismic Force-Resisting System

The commentary of Section E1.2.2 is applicable to the cold-formed steel shear walls with steel sheet sheathing by superseding Table C-E1.2.2 with Table C-E2.2.2 for the seismic design parameters.
### Table C-E2.2.2d

**United States and Mexico**

Design Coefficients and Factors for Shear Walls Sheathed With Steel Sheet Sheathing

<table>
<thead>
<tr>
<th>Basic Seismic Force-Resisting System</th>
<th>Seismic Response Modification Coefficient, R</th>
<th>System Over-strength Factor, ( \Omega_o )</th>
<th>Deflection Amplification Factor, ( C_d )</th>
<th>Structural System Limitations and Building Height (ft) Limitations</th>
<th>Seismic Design Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Bearing Wall Systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light-framed walls sheathed with steel sheets</td>
<td>6 ½</td>
<td>3</td>
<td>4</td>
<td>NL</td>
<td>NL</td>
</tr>
<tr>
<td>B. Building Frame Systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light-framed walls sheathed with steel sheets</td>
<td>7</td>
<td>2 ½</td>
<td>4 ½</td>
<td>NL</td>
<td>NL</td>
</tr>
</tbody>
</table>

* NL = Not Limited and NP = Not Permitted.

*Per ASCE/SEI 7 (ASCE, 2010)*, a bearing wall system is defined as a structural system with bearing walls providing support for all or major portions of the vertical loads, and a building frame system is defined as a structural system with an essentially complete space frame providing support for vertical loads. Per this *Standard*, shear walls are the basic seismic force-resisting elements. 

* The tabulated value of the overstrength factor, \( \Omega_o \), is permitted to be reduced by subtracting one-half for structures with flexible diaphragms, but shall not be taken as less than 2.0 for any structure. 

* See ASCE/SEI 7 (ASCE, 2010) Table 12.2-1 for additional footnotes. 

For SI: 1 ft = 0.305 m

#### E2.2.3 Type I or Type II Shear Walls

For relevant commentary on *Type I or Type II shear walls* with *steel sheet sheathing*, see Section E1.2.3.

#### E2.2.4 Seismic Load Effects Contributed by Masonry and Concrete Walls

For general commentary on seismic *load effects* contributed by masonry and concrete walls, see Section B1.4.

#### E2.3 Shear Strength [Resistance]

##### E2.3.1 Nominal Strength [Resistance]

The commentary for *nominal strength* [resistance] is comparable to that of *shear walls* sheathed with *wood structural panels*. Refer to Commentary Section E1.3.1.

Serrette et al. (2006) conducted tests on *cold-formed steel frame shear walls* utilizing structural adhesives. The walls with *steel sheet sheathing* attached by a structural adhesive exhibited a more nonlinear behavior with a less severe reduction in strength after the maximum resistance compared to the OSB sheathing; however, testing of such systems has been too limited to include specific provisions in this *Standard*. 

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E2.3.1.1 Type I Shear Walls

In the United States and Mexico: In 2007, in a precursor to this Standard (AISI S213), adjustments were made to Table E2.3-1 for 0.027 in. steel sheet, one side, based on testing at the University of North Texas (Yu, 2007). Designation thickness for stud, track and blocking associated with the existing 0.027 in. steel sheet tabulated values was increased from 33 mils (min.) to 43 mils (min.). New values were added for designation thickness for stud, track and blocking equal to 33 mils (min.).

E2.3.1.1.1 Effective Strip Method

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-E2.3.1.1.1-1. 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 consistence in resistance factors (0.60 for LRFD) specified in Standard Section E2.3.2, the original design equation in Yanagi and Yu (2014) was adjusted accordingly.

Figure C-E2.3.1.1.1-1 – Effective Strip Model for Steel Sheet Sheathing

E2.3.1.1.2 Wall Pier Limitations

For relevant commentary, see Section E1.3.1.1.1.
E2.3.1.3  Both Wall Faces Sheathed With the Same Material and Fastener Spacing

For relevant commentary, see Section E1.3.1.2.

E2.3.1.4  More Than a Single Sheathing Material or Fastener Configuration

For relevant commentary, see Section E1.3.1.3.

E2.3.1.2  Type II Shear Walls

For relevant commentary on Type II shear walls with steel sheet sheathing, see Section E1.3.1.2. Although the Dolan (1999, 2000a, 2000b) work discussed in Section E1.3.1.2 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.

E2.3.2 Available Strength [Factored Resistance]

The requirements are comparable to those of cold-formed steel light frame shear walls with wood sheathing. In Canada, the resistance factors for steel sheathed shear walls are obtained from the research (Balh, et. al, 2014; DaBreo, et. al., 2014). Refer to Commentary Section E1.3.2.

E2.3.3 Expected Strength [Probable Resistance]

The requirements are comparable to those of cold-formed steel light-frame shear walls with wood sheathing. Refer to Commentary Section E1.3.3.

E2.4  System Requirements

E2.4.1  Type I Shear Walls

E2.4.1.1  Limitations for Tabulated Systems

For relevant commentary, see Section E1.4.1.1.

E2.4.1.2  Required Strength [Effect Due to Factored Loads] for Chord Studs, Anchorage, and Collectors

For relevant commentary, see Section E1.4.1.2.

E2.4.1.3  Required Strength [Effect Due to Factored Loads] for Foundations

For relevant commentary, see Section E1.4.1.3.

E2.4.1.4  Design Deflection

The requirements for design deflections of the shear walls with steel sheet sheathing are comparable to those of shear walls with wood sheathings. Refer to Commentary Section E1.4.1.1. The $\rho$ term in Standard Equation E2.4.1.4-1 accounts for the effect of different sheathing materials on the observed response of walls with similar framing, fasteners and fastener schedules. Low values of $\rho$ for steel sheet sheathing are a result of shear buckling in the sheet. In 2012, in a precursor to this Standard (AISI S213), coefficients $\beta$ and $\rho$ in deflection equation C-E1.4.1.4-1 were revised for steel sheet sheathing based on research results compiled by Cobeen (2010).
E2.4.2 Type II Shear Walls

For relevant commentary, see Section E1.4.2.

E3 Cold-Formed Steel Light Frame Strap Braced Wall Systems

Cold-formed steel light frame strap braced wall systems are common in wind design and may be successfully employed in seismic design if designed and detailed with care. Specifically, the design must ensure the diagonal tension strap(s) yield and other limit states (fracture at the strap ends, buckling of the chord studs, etc.) are avoided for sufficient story drifts.

To the extent possible, the provisions of this section are written in a parallel format to those of Section E1, Cold-Formed Steel Light Frame Shear Walls Sheathed With Wood Structural Panels. It is recommended that the commentary of Section E1 be referenced in addition to the specifics of this section, particularly for discussions of the overall design basis provided in Section E1.

E3.2 Basis of Design

E3.2.1 Designated Energy-Dissipating Mechanism

For cold-formed steel light frame strap braced wall systems, yielding of the tensile straps provides the required energy dissipation; and the other elements of seismic load-resisting system, including connections, chord studs, and tracks, etc. should be designed for the force resulted from the expected strength [probable resistance] of the tensile straps.

E3.2.2 Seismic Design Parameters [Seismic Force Modification Factors and Limitations] for Seismic Force-Resisting System

In the United States and Mexico: AISI S400 is employed in conjunction with the applicable building code documents. For ASCE/SEI 7 (ASCE, 2010), the design coefficients, factors and limitations assigned to light-framed shear wall systems in ASCE/SEI 7 are reproduced in Table C-E3.2.2.

In Canada: When $R_dR_o$ is greater than 2 for diagonal strap braced walls, AISI S400 is mandatory. For diagonal strap braced walls, a designer has the option to choose an $R_dR_o$ of 1.625 for systems with a higher $R_dR_o$ to determine the seismic load and thereby avoid the special detailing in AISI S400. For this case, the height limitations for “Conventional Construction” in Table 1.2-1 in the Appendix 1 of AISI S400 would apply. Note that the lower $R_dR_o$ value of 1.625 associated with diagonal strap bracing was chosen to ensure that the system remains essentially elastic. Additional guidance is provided in Section E7.
Table C-E3.2.2d
United States and Mexico
Design Coefficients and Factors for Strap Braced Wall Systems

<table>
<thead>
<tr>
<th>Basic Seismic Force-Resisting System b</th>
<th>Seismic Response Modification Coefficient, R</th>
<th>System Over-strength Factor, Ωc</th>
<th>Deflection Amplification Factor, Cd</th>
<th>Structural System Limitations and Building Height (ft) Limitations a</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Bearing Wall Systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light-framed wall systems using flat strap bracing</td>
<td>4</td>
<td>2</td>
<td>3½</td>
<td>NL</td>
</tr>
</tbody>
</table>

a NL = Not Limited and NP = Not Permitted.
b Per ASCE/SEI 7 (ASCE, 2010), a bearing wall system is defined as a structural system with bearing walls providing support for all or major portions of the vertical loads. Per this standard, braced frames are the basic seismic force resisting elements.
c The tabulated value of the overstrength factor, Ωo, is permitted to be reduced by subtracting one-half for structures with flexible diaphragms, but shall not be taken as less than 2.0 for any structure.
d See ASCE/SEI 7 (ASCE, 2010) Table 12.2-1 for additional footnotes.

For SI: 1 ft = 0.305 m

E3.2.3 Seismic Load Effects Contributed by Masonry and Concrete Walls

For general commentary on seismic load effects contributed by masonry and concrete walls, see Section B1.4.

E3.3 Shear Strength [Resistance]

E3.3.1 Nominal Strength [Resistance]

The nominal shear strength [resistance] is calculated based on projecting the nominal strength [resistance] of the tensile straps on the horizontal axis, ignoring the strength of the buckled compressive straps, and assuming pinned connections. If the strap is not across the full height and length of the wall, then the height and length of the area that the strap occupies should be used in this section and the horizontal forces must be resolved in detailed blocking.

E3.3.2 Available Strength [Factored Resistance]

Given that the designated energy-dissipating mechanism defines the response of the full wall, the resistance (φ) and safety factors (Ω) provided for the strap braced wall system are based on the yielding limit state and utilize the φ and Ω established in AISI S100 [CSA136].

E3.3.3 Expected Strength [Probable Resistance]

For a strap braced wall, the wall expected strength [probable resistance] can be determined in accordance with the following:

\[ V_n = \frac{R_y A_y F_y w}{\sqrt{h^2 + w^2}} \]  

(Eq. C-E3.3.3-1)
where

\[ h = \text{Height of the wall} \]
\[ w = \text{Length of the wall} \]
\[ R_y = \text{Value per Standard Section A3.2} \]
\[ A_g = \text{Gross area of the flat \textit{straps} (sum of the area of the tensile \textit{straps} on both sides of the wall)} \]
\[ F_y = \text{Yield stress of the flat \textit{straps}} \]

**E3.4 System Requirements**

**E3.4.1 Limitations on System**

Proper detailing is required to ensure that yielding of the \textit{strap} is the realized \textit{limit state}. Special seismic requirements for \textit{strap braced walls} were first introduced in 2007 in a precursor to this \textit{Standard} based largely on the research of Rogers at McGill University (Al-Kharat and Rogers, 2005, 2006, 2007), testing by Jim Wilcoski of the U.S. Army Corps of Engineers, and engineering judgment. The \textit{Standard} provides three methods for ensuring the yielding \textit{limit state} of the \textit{strap} at the critical \textit{strap}-to-stud and track connection: (1) weld, (2) avoid fracture in the net cross-section at expected strength levels, or (3) test. Method (1), welding, is generally the simplest solution – the weld should be designed for the expected strength of the \textit{strap}. Method (2) requires that the expected ultimate-to-yield ratio be greater than 1.2 (to ensure material ductility) and that the expected net section fracture strength is greater than the expected yield strength of the \textit{strap}. Velchev and Rogers (2008) demonstrated that screw-connected walls designed following Method (2) can reach similar inelastic drifts to the weld-connected walls. This study also demonstrated that the use of reduced width fuse braces makes the brace end \textit{connection} requirements easier to satisfy; however, the research report outlines some key design aspects to using these braces that need to be considered. The \textit{Standard} Equations E3.4.1-1 and E3.4.1-2 establish that net section fracture does not control the behavior of the \textit{strap}. This further implies that \textit{available strength} [\textit{factored resistance}] in net section fracture need not be checked.
The slenderness of tension-only diagonal strap bracing is not limited because straps are expected to be installed taut and are typically not used in an exposed condition where vibration of the strap may be an issue.

Comeau and Rogers (2008) demonstrated that allowing for supplementary holes in regular braces due to attaching the straps with screws to the interior studs does not have an adverse impact on the overall ductility. However, strict control was used in the size of the screws (No. 8) and number of screws (1 per brace to interior stud connection). The use of multiple screws or screws close to the edge of a brace may reduce the lateral ductility. It is assumed that penetrations in the braces by the use of No. 6 screws for the application of drywall or similar products would not be detrimental given the observed performance of the walls with No. 8 screws installed in the braces. The one exception to this would be the use of screws in the fuse section of a reduced width brace (short fuse section).

The Standard does not require that the horizontal shear force from the diagonal brace be resisted by a device connected directly to the diagonal brace and anchored directly to the foundation or supporting structural element when the track is designed to resist the horizontal shear force by compression or tension because testing (Al-Kharat and Rogers, 2005, 2006, 2007) has shown satisfactory performance of such assemblies. Velchev and Rogers (2008) investigated various methods of increasing the track capacity such that the expected yield strength of the brace can be carried. This study concluded that it was most efficient to use thicker track. Track that is reinforced requires significant effort in terms of labor, and it is not clear as to the length of track that needs to be reinforced, nor the number of connections. Extending the track (i.e., using the track in tension) may also be a viable solution.

When subject to lateral force, narrow strap-braced shear walls place bending demands in addition to axial demands on the boundary elements of the shear wall. Strap-braced shear walls that have an aspect ratio (h:w) of 1:1 have insignificant bending demands; however, walls with the aspect ratio (h:w) of 2:1 have been experimentally shown to require

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**Figure E3.4.1-1 – Regular Brace Versus Reduced Width Fuse Brace (Velchev and Rogers, 2008)**

---

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consideration of the bending demand in the chord studs. Analysis indicates that the bending demands quickly increase for walls with aspect ratios greater than 1:1, and the Standard has chosen to require consideration of these moments for aspect ratios greater than 1.9:1. To protect the energy-dissipating mechanism of strap yielding in walls with aspect ratios greater than 1.9:1, the boundary elements must be designed for the bending moments that develop at the expected strength levels of the strap in the strap-braced wall. To determine these bending moments, the engineer is required to perform a structural analysis where the boundary element connections (stud-to-track) are fully fixed. The assumption of full joint fixity provides a conservative approximation of the bending demand and has been shown to accurately predict observed failures in tests on strap-braced shear walls. See Mirzeai et al. (2015) for a complete discussion.

The structural analysis may be completed using frame analysis in software or in closed-form as presented here. Lateral load on a strap-braced shear wall is resisted by truss action (subscript T) and frame action (subscript F). The stiffness of each individually in resisting shear is:

\[
k_T = \left[ \frac{h^3}{b^2EA_c} + \frac{(h^2 + b^2)^{1.5}}{b^2EA_s} \right]^{-1} \quad (Eq. C-E3.4.1-1)
\]

\[
k_F = \left( \frac{6I_b + 4b}{I_c} + \frac{h}{b} \times \frac{h^3}{24EI_c} \right)^{-1} \quad (Eq. C-E3.4.1-2)
\]

where
- \(k_T\) = Lateral stiffness of truss system
- \(h\) = Height of wall
- \(b\) = Width of wall
- \(E\) = Modulus of elasticity of steel
- \(A_c\) = Cross-sectional area of chord stud
- \(A_s\) = Cross-sectional area of strap
- \(k_F\) = Lateral stiffness of frame system
- \(I_b\) = Moment of inertia of track about the axis of bending under frame action
- \(I_c\) = Moment of inertia of chord stud about the axis of bending under frame action

For a shear force, \(V\) (developed from the expected strength of the strap), the deflection, \(\delta\), of the wall is:

\[
\delta = \frac{V}{k_F + k_T} \quad (Eq. C-E3.4.1-3)
\]

The amount of shear attributed to the frame action, \(V_F\), is:

\[
V_F = (k_F)\delta \quad (Eq. C-E3.4.1-4)
\]

\(V_F\) results in a moment at the base of the chord stud \((M_b)\) and a moment above the hold-down \((M_h)\) due to frame action, which can be calculated by using Equations C-E3.4.1-5 and C-E3.4.1-6:
\[
M_b = \frac{V_F h}{2} \left( \frac{3I_b h}{I_c b} + \frac{1}{6I_b h + 1} \right) \quad (Eq. C-E3.4.1-5)
\]

\[
M_h = M_b \left( \frac{M_b}{0.5V_F} - h_0 \right) \quad (Eq. C-E3.4.1-6)
\]

where \( h_0 \) is the distance from the base to the top of the hold-down. The assumption, consistent with experimental observations, is that the hold-down stiffens the chord stud and the critical location for axial and bending demands is at the cross-section of the chord stud immediately adjacent to the end of the hold-down. As a result, the Standard requires that this location (\( M_b \)) be checked—this provides some relief from the large bending demands that are assumed from the assumption of full joint fixity.

The deflection calculated per Equation C-E3.4.1-3 is not intended to be an approximation of actual system deflection for the purposes of seismic design. The provisions for narrow strap braced shear walls do not allow frame action to be considered in the nominal strength [nominal resistance], but do require that frame action be considered to ensure the desired energy-dissipating mechanism of strap yielding is achieved.

**E3.4.2 Required Strength [Effect of Factored Loads] for Seismic Force-Resisting System**

To develop a desirable response, this Standard requires that elements of the lateral force-resisting system that deliver seismic forces to the diagonal straps (other than the diaphragm) be capable of developing the expected yield strength of the diagonal strap bracing member or, if lower, the expected overstrength \( \Omega_o \) times the design seismic load [United States and Mexico] or seismic loads calculated with \( R_dR_o = 1.0 \) [Canada] of the diagonal strap bracing member.

The Standard requires that eccentricity be considered in the design where single-sided diagonal strap bracing is provided. Single-sided diagonal strap bracing causes an eccentric compression force to be applied to the chord studs, which results in a strong axis moment in addition to the axial force. The eccentricity is half of the stud depth.

**E3.4.3 Required Strength [Effect of Factored Loads] for Foundations**

See the commentary to Section E1.4.1.3 for additional discussion.

**E3.4.4 Design Deflection**

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, tilting and bearing at connections if screws are used, and a lateral contribution from hold-down and anchorage deformation, as well as additional deflections that may result for other components in a structure (for example, wood sills and raised floors). Loose straps permit lateral displacement without resistance. This Standard requires that straps be installed taut.
**E4 Cold-Formed Steel Special Bolted Moment Frames (CFS–SBMF)**

*Cold-Formed Steel* Special Bolted Moment Frame (CFS–SBMF) systems are a unique *cold-formed steel seismic force-resisting system*. The basic configuration uses HSS uprights and relatively stocky *cold-formed steel* channel beams with a specially detailed bolt group at the beam-to-column *connection*. Due to limitations of existing testing, the system is limited to a single story (and additional limitations as detailed herein). This specialized system has existing applications in mezzanine and residential structures.

To the extent possible, this section is provided in a parallel format to the others of Chapter E. However, due to the unique nature of the system as compared with *shear walls* and *strap-braced walls* and reflecting the separate development (AISI S110-07w/S1-09 is the precursor to this section), the provisions have a number of unique features that are addressed in this commentary.

**E4.1 Scope**

The provisions provided in this section do not apply to Canada. The *nominal*, *available*, and expected strengths provided here are anticipated to be applicable in Canada; however, since the 2014 NBCC does not provide *seismic performance factors* for this system, the engineer would be required to use elastic design ($R_d R_o = 1$), which removes the advantage of employing the system regardless of its performance.

**E4.2 Basis of Design**

**E4.2.1 Designated Energy- Dissipating Mechanism**

*Cold-Formed Steel* Special Bolted Moment Frame (CFS–SBMF) systems are expected to experience substantial inelastic deformation during significant seismic events. It is expected that most of the inelastic deformation will take place at the bolted *connections*, due to slip and *bearing*. To achieve this, beams and columns should have sufficient strength when subjected to the forces resulting from the motion of the *design earthquake*. Hong and Uang (2004) tested a total of nine full-scale beam-column specimens; see Table C-E4.2-1 for the test matrix. These specimens simulated a portion of an interior beam-to-column subassembly with a column height of 8.25 ft (2.51 m) and a bay width of 11 ft (3.35 m). This testing program demonstrated that this type of system can develop significant ductility. Figure C-E4.2-1 illustrates the typical hysteresis behavior. All specimens developed a story drift capacity significantly larger than the 0.04 radians required for Special *Moment Frames* (SMF) in the ANSI/AISC 341 (AISC, 2010).
Figure C-E4.2-1 Typical Hysteresis Behavior of CFS–SBMF Systems (Hong and Uang, 2004)

Table C-E4.2-1
Test Matrix

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Beam</th>
<th>Column</th>
<th>Bearing Plate</th>
<th>Bolt configuration* , in.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>a, in. (mm)</td>
<td>b, in. (mm)</td>
</tr>
<tr>
<td>1, 2</td>
<td>2C12 × 3 1/2 × 0.105</td>
<td>HSS8 × 8 × 1/4</td>
<td>0.135 (3.43)</td>
<td>2 1/2 (63.5)</td>
</tr>
<tr>
<td>3</td>
<td>2C16 × 3 1/2 × 0.105</td>
<td>HSS8 × 8 × 1/4</td>
<td></td>
<td>3 (76.2)</td>
</tr>
<tr>
<td>4</td>
<td>2C16 × 3 1/2 × 0.105</td>
<td>HSS8 × 8 × 1/4</td>
<td>0.135 (3.43)</td>
<td>3 (76.2)</td>
</tr>
<tr>
<td>5, 6, 7</td>
<td>2C16 × 3 1/2 × 0.135</td>
<td>HSS8 × 8 × 1/4</td>
<td></td>
<td>3 (76.2)</td>
</tr>
<tr>
<td>8, 9</td>
<td>2C20 × 3 1/2 × 0.135</td>
<td>HSS10 × 10 × 1/4</td>
<td>N/A</td>
<td>3 (76.2)</td>
</tr>
</tbody>
</table>

Note: * 1 in. (25.4 mm) diameter A325 bearing type high-strength bolts.
See Figure C-E4.2-1 for definitions of dimensions a, b, and c.
E4.2.2 Seismic Design Parameters for Seismic Force-Resisting System

The explanations in Commentary Section E1.2.2 are generally applicable to Cold-Formed Steel Special Bolted Moment Frame (CFS-SBMF) after superseding Table C-E1.2.2 with Table C-E4.2.2 for the seismic design parameters.
Table C-E4.2.2b

United States and Mexico
Design Coefficients and Factors for Cold-Formed Steel
Special Bolted Moment Frames (CFS–SBMF)

<table>
<thead>
<tr>
<th>Basic Seismic Force-Resisting System</th>
<th>Seismic Response Modification Coefficient, R</th>
<th>System Over-strength Factor, ( \Omega_o )</th>
<th>Deflection Amplification Factor, ( C_d )</th>
<th>Structural System Limitations and Building Height (ft) Limitations (^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. Moment-resisting frame systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold-formed steel-special bolted moment frames</td>
<td>3 ½</td>
<td>3</td>
<td>3 ½</td>
<td>35</td>
</tr>
</tbody>
</table>

\(^a\) NL = Not Limited and NP = Not Permitted.
\(^b\) See ASCE/SEI 7 (ASCE, 2010) Table 12.2-1 for additional footnotes.

For SI: 1 ft = 0.305 m

E4.2.3 Seismic Load Effects Contributed by Masonry and Concrete Walls

For general commentary on seismic load effects contributed by masonry and concrete walls, see Section B1.4.

E4.3 Strength

E4.3.1 Required Strength

The required strength [effect due to factored loads] of a seismic force-resisting system should be determined in accordance with the applicable building code. An amplification or overstrength factor, \( \Omega_o \), applied to the horizontal portion of the earthquake load \( E \) is prescribed in the applicable building code.

In 2009, the system overstrength factor, \( \Omega_o \), was decreased to 3.0 and deflection amplification factor, \( C_d \), was increased to 3.5. These changes reflect recommendations from the Building Seismic Safety Council Provisions Update Committee.

E4.3.1.1 Beams and Columns

To provide elastic beams and columns and to mobilize the expected inelastic deformation at the bolted connection, beams and columns should have sufficient strength when subjected to the forces resulting from the design earthquake. To achieve this, the required strength [effect of factored loads] of beams and columns should be determined in accordance with the expected strength [probable resistance] of the connections.

E4.3.1.2 Bolt Bearing Plates

Most of the time, the beam web bearing strength is not enough to provide slippage in the connection. Accordingly, as shown in Figure C-E4.2-1, bearing plates can be used to increase the bearing strength of the beam web. The bearing plate thickness can be added to the web thickness in bearing calculations if the holes have been drilled through both the beam web and the bearing plate after welding the bearing plate.
E4.3.2 Available Strength

The available strength [resistance] of systems, members and connections should be determined in accordance with AISI S100, except as modified by this Standard.

E4.3.3 Expected Strength

To ensure that inelastic action will only occur at the bolted connections, capacity--based design principles should be followed to calculate the maximum force that can be developed in these connections at the design story drift. Beams and columns are then designed to remain essentially elastic based on this maximum force.

It is common that all the beams in CFS–SBMF are the same size, and so are all the columns. All the beam and column connections have the same bolt configuration. This leads to the assumption of the desirable yield mechanism with the expected distribution of column shears as shown in Figure C-E4.3.3-1(a). The lateral load response of one column is shown in Figure C-E4.3.3-1(b). At the design story drift, \( \Delta \), the column shear is \( (V_S + R_t V_B) \), and the expected moment at the bolt group is

\[
M_e = h(V_S + R_t V_B)
\]

(Eq. C-E4.3.3-1)

where \( h \) is story height, and \( R_t \) is the factor given in Standard Table A3.2-1.

In the above equation, \( V_S \) is the column shear that causes the bolt group to slip [Point a in Figure C-E4.3.3-1(b)]; \( R_t \) is the ratio of expected tensile strength to specified minimum tensile strength. The bolt hole oversize allows the bolt group to rotate, which produces a component of story drift of \( \Delta_S \) in Figure C-E4.3.3-1(b), until bolt bearing occurs (Point b). To overcome the bearing resistance, the additional column shear required to reach the design story drift (Point c) is defined as \( R_t V_B \).

\[
\sum^n (V_S + R_t V_B)
\]

(a) Shear Force Distribution

(b) Structural Response of One Column

Figure C-E4.3.3-1 General Structural Response of CFS–SBMF System
Figure C-E4.3.3-2 shows a bolt group with an eccentric shear at the column base. The instantaneous center (IC) of rotation concept (Crawford and Kulak, 1971) can be applied to compute the required response quantities. At the bolt level, the slip resistance of one bolt, $R_S$, is

$$R_S = kT$$  \hspace{1cm} (Eq. C-E4.3.3-2)

where $k = \text{slip coefficient}$ and $T = \text{snug-tight bolt tension}$. A value of $k = 0.33$ is assumed, and the value of $T$ ranges from 10 kips (44.5 kN) to 25 kips (111 kN) for 1-in. (25.4 mm) diameter snug-tight bolts. For design purposes, a value of $T$ equal to 10 kips (44.5 kN) is recommended for 1-in. (25.4 mm) diameter snug-tight bolts.

The slip range, $\Delta_S$, in Figure C-E4.3.3-1(b) is a function of the bolt hole oversize and can be computed as

$$\Delta_S = \frac{2h_{os}h}{d_{max}}$$  \hspace{1cm} (Eq. C-E4.3.3-3)

where
- $h_{os} = \text{Hole oversize (difference between hole diameter and bolt diameter)}$
- $d_{max} = \text{Outermost bolt arm length from instantaneous center (IC)}$

The bearing resistance of a bolt is

$$R_B = R_{ult}(1 - e^{-\mu\delta})^\lambda$$  \hspace{1cm} (Eq. C-E4.3.3-4)

where
- $\delta = \text{Bearing deformation}$
- $R_{ult} = \text{Ultimate bearing strength}$
- $e = 2.718$
- $\mu$ and $\lambda = \text{Regression coefficients}$

For application in Cold-Formed Steel Special Bolted Moment Frame (CFS-SBMF)
systems, $\mu = 5$ and $\lambda = 0.55$ gave a reasonable correlation to available test results (Sato and Uang, 2007).

![Sample Correlation of Bolted Connection Response](image)

**Figure C-E4.3.3-3 Sample Correlation of Bolted Connection Response**

Based on the above procedure, sample correlation of two test specimens is shown in Figure C-E4.3.3-3.

Values of $V_S$ and $\Delta_S$ can be computed by using the instantaneous center of rotation theory, and Table C-E4.3.3-1 shows the results for some commonly used bolt configurations and story heights. Equations E4.3.3-2 and E4.3.3-7 of the Standard are derived from regression analysis of Table C-E4.3.3-1 to facilitate design.

Next, consider $V_B$ in Equation C-E4.3.3-1 (or Standard Equation E4.3.3-1). Referring to Point c in Figure C-E4.3.3-1(b), the *design story drift* ($\Delta$) is composed of three components: (1) the recoverable elastic component which is related to the lateral stiffness, $K$, of the frame, (2) the slip component, $\Delta_S$, from Standard Equation E4.3.3-7, and (3) the bearing component:

$$\Delta_B = \Delta - \Delta_S - \frac{nM_e}{hK}$$  \hspace{1cm} (Eq. C-E4.3.3-5)

where
- $n$ = Number of columns in a frame line (i.e., number of bays plus 1)
- $M_e$ = Expected moment at a bolt group as defined in Standard Section E4.3.3.3

Applying the instantaneous center of rotation concept to the eccentrically loaded bolt group in Figure C-E4.3.3-2 by using the bolt bearing relationship in Equation C-E4.3.3-4, the relationship between the bearing component of the story drift, $\Delta_B$, and the bearing component of the column shear, $V_B$, can be established. Figure C-E4.3.3-5(a) shows a sample result. For a given story height, the last point of each curve represents the ultimate when the bearing deformation of the outermost bolt reaches 0.34 in. (8.6 mm).

Values of $V_{B,max}$ and $\Delta_{B,max}$ for some commonly used bolt configurations and story heights are computed. Standard Equations E4.3.3-4 and E4.3.3-6 are derived from regression analysis of Table C-E4.3.3-2 to facilitate design.
The Bearing Deformation Adjustment Factor, $C_{DB}$, in Equation C-E4.3.3-7 accounts for the additional contribution of bearing deformation from the stronger component.

Refer to Point a in Figure C-E4.3.3-4, where the ultimate bearing deformation [0.34 in. (8.6 mm)] of the weaker component is reached. Since the bearing forces of the bolt between both the weaker and stronger components are identical, it can be shown that the corresponding bearing deformation of the stronger component (i.e., Point b) is

$$\delta_s = -\frac{1}{5} \ln \left[ 1 - 0.817 \left( \frac{tF_u}{tF_u} \right)^{1.82} \right]$$  \hspace{1cm} (Eq. C-E4.3.3-6)

The $C_{DB}$ factor represents the ratio between the total bearing deformation and 0.34 in. (8.6 mm).

$$C_{DB} = \frac{0.34 + \delta_s}{0.34} = 1.0 - 0.588 \ln \left[ 1 - 0.817 \left( \frac{tF_u}{tF_u} \right)^{1.82} \right]$$  \hspace{1cm} (Eq. C-E4.3.3-7)

Note that the $\Delta_{B,0}$ values correspond to the maximum drift deformation when the bearing deformation is contributed by the weaker component only.

Normalizing each curve in Figure C-E4.3.3-5(a) by its own ultimate limit state, Figure C-E4.3.3-5(b) shows that a normalized relationship between $V_B$ and $\Delta_B$ can be established:

$$\left( \frac{V_B}{V_{B,\text{max}}} \right)^2 + \left( 1 - \frac{\Delta_B}{\Delta_{B,\text{max}}} \right)^{1.43} = 1$$  \hspace{1cm} (Eq. C-E4.3.3-8)
(Column: HSS 8 × 8 × 1/4, Beam: 2C12 × 31/2 × 0.105, Bearing Plate: 0.135 in.)

(a) Bearing Response

(b) Normalized Bearing Response

Figure C-E4.3.3-5 Sample Result of Bearing Response

Iteration is required to compute the expected moment, $M_e$, in Equation C-E4.3.3-1. The following value is suggested as the initial value for $\Delta_B$:

$$\Delta_B = \frac{[\Delta - (\Delta_S + \Delta_y)]K}{nV_{B,\text{max}} / \Delta_{B,\text{max}} + K}$$  \hspace{1cm} (Eq. C-E4.3.3-9)

where $\Delta_y$ is the story drift at Point a in Figure C-E4.3.3-1(b).
Table C-E4.3.3-1
Values of GS and GDS for Eccentrically Loaded Bolt Groups

\[ V_S = N \times G_S \times R_s \]
\[ \Delta S = G_{DS} \times h_{os} \]

where
- \( V_S \) = Column shear causing slip
- \( R_s \) = Slip strength per bolt
- \( k \times T \) = Slip coefficient
- \( T \) = Snug-tight bolt tension
- \( h \) = Story height, ft
- \( a, b, \) and \( c \) = Bolt spacing, in.
- \( \Delta S \) = Slip drift due to slip
- \( G_S, G_{DS} \) = Coefficient tabulated below
- \( h_{os} \) = Hole oversize

<table>
<thead>
<tr>
<th>c, in.</th>
<th>h, ft</th>
<th>Bolt spacing a and b, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>a = 2-1/2, b = 3</td>
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<tr>
<td>4-1/4</td>
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<td>G_S</td>
</tr>
<tr>
<td>8</td>
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<td>9</td>
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<tr>
<td>10</td>
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<td>0.237</td>
</tr>
<tr>
<td>11</td>
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<td>0.216</td>
</tr>
<tr>
<td>13</td>
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</table>

|       |      | G_S | G_{DS} | G_S | G_{DS} | G_S | G_{DS} |
| 6-1/4 |      | 0.355 | 36.2 | 0.460 | 25.8 | 0.597 | 18.2 |
| 8     |      | 0.315 | 40.9 | 0.410 | 29.3 | 0.531 | 20.9 |
| 9     |      | 0.284 | 45.6 | 0.369 | 32.9 | 0.479 | 23.5 |
| 10    |      | 0.259 | 50.4 | 0.335 | 36.4 | 0.436 | 26.2 |
| 11    |      | 0.218 | 59.8 | 0.284 | 43.5 | 0.370 | 31.6 |
| 13    |      | 0.189 | 69.3 | 0.246 | 50.5 | 0.321 | 37.0 |
| 15    |      | 0.167 | 78.7 | 0.217 | 57.6 | 0.283 | 42.5 |
| 17    |      | 0.150 | 88.2 | 0.194 | 64.7 | 0.253 | 48.0 |
| 19    |      | 0.135 | 97.6 | 0.176 | 71.8 | 0.229 | 53.5 |
| 21    |      | 0.124 | 107  | 0.161 | 78.9 | 0.210 | 59.0 |
| 23    |      | 0.114 | 117  | 0.148 | 85.9 | 0.193 | 64.6 |
| 25    |      | 0.105 | 126  | 0.137 | 93.0 | 0.179 | 70.1 |
| 27    |      | 0.0977| 135  | 0.127 | 100  | 0.166 | 75.7 |
| 29    |      | 0.0915| 145  | 0.119 | 107  | 0.156 | 81.2 |
| 31    |      | 0.0859| 154  | 0.112 | 114  | 0.146 | 86.8 |
| 33    |      | 0.0810| 164  | 0.105 | 121  | 0.138 | 92.4 |

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For Eccentrically Loaded Bolt Groups

\( \Delta B_{\text{max}} = C_{\text{DB}} \times \Delta B_{0} \)

\( \Delta B_{0} \) = Maximum bearing drift deformation
\( C_{\text{DB}} \) = Bearing deformation adjustment

<table>
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<tr>
<th>( c, \text{ in.} )</th>
<th>( h, \text{ ft} )</th>
<th>Bolt spacing ( a ) and ( b ) in.</th>
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<th>( a = 3, b = 6 )</th>
<th>( a = 3, b = 10 )</th>
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<td>( G_B )</td>
<td>( \Delta B_{0} ) in.</td>
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<td>( \Delta B_{0} ) in.</td>
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E4.4 System Requirements

E4.4.1 Limitations on System

The height limitation of 35 feet is based on practical use only and not from any limits on the CFS-SBMF system strength. It is possible for the CFS-SBMF system to meet drift limits and support the loads associated with larger system heights, provided that members are sized accordingly and the design methods contained within this Standard are adhered to. The Standard was developed assuming that the CFS–SBMF system uses the same-size beams and same-size columns throughout. It was also assumed that the system would engage all primary columns, which support the roof or floor above, and that those columns were pin-based, warping free, twist restrained, and would be supported on a level floor or foundation. The column base connection should be detailed to minimize the column end moment.

In 2009, the Standard was revised to reflect these assumptions in the requirements for the system.

The test matrix in Table C-E4.2-1 was developed to allow for the effect of local buckling on strength degradation. In 2009, modifications were made for consistency with the test database.

The Standard permits alternate methods of computing the design story drift, $\Delta$. From Figure C-E4.4.1-1, the design story drift, $\Delta$, resulting from the motion of the design earthquake is needed to compute the required force in the beams and columns. The design story drift is generally computed in accordance with the applicable building code but modified by using an empirical deflection amplification factor, $C_d$. The basis of the $C_d$ factor in the Standard for a CFS–SBMF system follows.

![Figure C-E4.4.1-1 General Response of CFS–SBMF System](image_url)

Figure C-E4.4.1-1 shows the general response of a CFS–SBMF system. For design purposes, the elastic seismic force produced by the design earthquake (Point e) is reduced by a response modification coefficient, $R$, of 3.5; the corresponding story drift at Point d is $\Delta_d$. The bolted connections actually slip at Point a, producing pseudo-yielding at a base shear of $nV_S$, where $V_S$ is computed from Standard Section E4.3.3, and n is the number of columns in a frame line. The ratio between the base shears at Points e and a is the system ductility reduction factor:
$R_\mu = \frac{V_{DBE}}{nV_S}$  

(Eq. C-E4.4.1-1)

where $V_{DBE}$ is the elastic base shear corresponding to the design basis earthquake, and $R_\mu$ is the system ductility reduction factor.

The ratio between the story drifts at Point c and Point a is defined as the system ductility factor:

$$\mu = \frac{\Delta}{\Delta_y}$$  

(Eq. C-E4.4.1-2)

Newmark and Hall (1982) proposed a relationship between $\mu$ and $R_\mu$ for a single-degree-of-freedom system that responds in an elasto-perfectly plastic (EPP) manner (path o-a-b-c):

$$R_{\mu(\text{N-H})} = \begin{cases} \frac{\mu}{\sqrt{2\mu - 1}} & \text{for } T \geq T_S \\ 1.2 & \text{for } T \leq T_C \end{cases}$$  

(Eq. C-E4.4.1-3)

where $T_S$ is defined in the applicable building code, and $T_C = T_S \frac{\sqrt{2\mu - 1}}{\mu}$. Since the actual response of a CFS-SBMF system exhibits a significant hardening (path o-a-b-c) when the bolts are in bearing, for a given ductility factor it is expected that the ductility reduction factor should be higher than that given in Equation C-E4.4.1-3. A parametric study was conducted, and the result in Table C-E4.4.1-1 shows that it is reasonable to assume the following (Sato and Uang, 2007):

$$R_\mu = 1.2 R_{\mu(\text{N-H})}$$  

(Eq. C-E4.4.1-4)

For the period not shorter than $T_S$ (i.e., $T \geq T_S$), the above equation gives $R_\mu = 1.2\mu$. Using the relationships in Figure C-E4.4.1-1,

$$\Delta = \mu \Delta_y = \frac{R_\mu}{1.2} \Delta_y = \frac{V_{DBE}}{1.2(nV_S)} \left( \frac{nV_S}{K} \right)$$

$$= \frac{V_{DBE}}{1.2K} = 0.83\Delta_{DBE} = (0.83R)\Delta_d$$  

(Eq. C-E4.4.1-5)

that is, the deflection amplification factor, $C_d$, is 0.83. For an $R$ value of 3.5, the value of $C_d$ is about 3.0. Based upon recommendations from the Provisions Update Committee (PUC) of the Building Seismic Safety Council (BSSC), however, the value of $C_d$ has been conservatively increased to 3.5.

For $T \leq T_C$, a simple expression for $C_d$ cannot be derived. Following a similar procedure would give the following for the design story drift (Sato and Uang, 2007):

$$\Delta = \frac{1}{2K} \left( nV_S + 0.7 \frac{V_{DBE}^2}{nV_S} \right)$$  

(Eq. C-E4.4.1-6)

where

$$T_C = T_S \left( nV_S \sqrt{2V_{DBE}/nV_S - 1} \right)$$  

(Eq. C-E4.4.1-7)

For structures having a period between $T_S$ and $T_C$, $\Delta$ can be determined from linear interpolation.
### Table C-E4.4.1-1

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<tr>
<th>Ductility Factor</th>
<th>$\mu = 4$</th>
<th>$\mu = 6$</th>
<th>$\mu = 8$</th>
</tr>
</thead>
<tbody>
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<td>$R_{R\mu(\text{actual})}/R_{R\mu(\text{EPP})}$</td>
<td>1.14</td>
<td>1.23</td>
<td>1.26</td>
</tr>
</tbody>
</table>

In 2009, the drift limit in AISI S110 (precursor of AISI S400) was deleted in favor of the current allowable story drift in ASCE/SEI 7, which limits the drift to a range from 0.025h for Occupancy Category I and II buildings and structures to as little as 0.015h for Occupancy Category IV buildings and structures. The intent of these drift limits is to control damage to nonstructural components that are attached to the lateral force resisting system. However, Footnote c of Table 12.12-1 in ASCE/SEI 7 (ASCE, 2010) waives the drift limit for single-story structures with interior walls, partitions, ceilings, and exterior wall systems that have been designed to accommodate the story drifts. This footnote is certainly valid in the case of most CFS-SBFM systems, which are commonly used in industrial platforms. However, for nonstructural components that are susceptible to drift damage, the more stringent drift limits specified in Table 12.12-1 in ASCE/SEI 7 (ASCE, 2010) should be applied.

For CFS-SBFM, P-Δ effects should conform to the requirements of the applicable building code.

### E4.4.2 Beams

Unlike the strong column-weak beam concept adopted in ANSI/AISC 341 for Special Moment Frame design, buckling of a cold-formed steel beam is the most undesirable failure mode in CFS-SBFM systems. As shown in Figure C-E4.4.2-1, rapid strength degradation would occur when the beam web flat depth-to-thickness ratio ($w/t$) is 147. Two measures are taken to avoid such strength degradation: (1) limit the design story drift ratio to no greater than 0.05, and (2) limit the $w/t$ ratio to no greater than $\frac{y_F}{E_1^{(18.6)}}$.

In 2009, ASTM A653 was specified for cold-formed steel C-section members based on the test database. In addition, limitations on the beam depth, thickness, and surface treatment were added to reflect the test database.

![Figure C-E4.4.2-1 Beam Local Buckling Effect on Strength Degradation (Hong and Uang, 2004)](image)

A single-channel beam configuration is permitted by this Standard; however, only the double-channel beam configuration has been tested to date. Since the single-channel configuration is unsymmetrical, it could possibly induce torsion into the channel and...
column. In 2009, further clarification was added, requiring designers to demonstrate that the torsional effect is properly taken into account when the design uses a single-channel beam.

Typically, the beam top flanges are connected to a floor deck (normally steel deck and plywood). This will resist the small torsion in the column due to the load on one side only. Also, designers should include in their column check the ability to add the torsion stress to the bending and axial load stresses to ensure a properly designed column.

If a system is constructed without deck attached to the beam flanges, the torsion forces should be included in the column design.

Consider a seismic force at the top of the column which is typically 2 to 3 kips (8.90 to 13.3 kN). The seismic force would result in a torsional moment of \((4 \times 3 = 12 \text{ in-kips} (1.36 \text{ m-kN}))\) or \(5 \times 3 = 15 \text{ in-kips} (1.69 \text{ m-kN})\). The seismic moment in the column is in the range of 360 to 600 in-kips (40.7 to 67.8 m-kN) with axial loads of 30 to 50 kips (133 to 222 kN). In this case, the torsional moment would not control the design.

### E4.4.3 Columns

Column buckling is not as detrimental as beam buckling in terms of strength degradation, partly because the HSS column section is comprised of stiffened elements. When a slender section in accordance with ANSI/AISC 360 (AISC, 2010) is used, test results show that significant strength degradation may occur (see Figure C-E.4.4.3-1). This undesirable failure mode can be avoided by limiting both the flat width-to-thickness ratio to \(1.40 \sqrt{E/F_y}\) and the maximum story drift to 3 percent of the story height.

In 2009, to reflect limitations of the test database, ASTM A500 for hollow structural section (HSS) members painted with a standard industrial finished surface was specified for columns. Upper and lower limits on the column depths were added as well to mirror the limitations of the tests. In 2015, ASTM A1085 was added as a suitable material for HSS columns.

![Figure C-E.4.4.3-1 Column Local Buckling Effect on Strength Degradation (Hong and Uang, 2004)](image)

### E4.4.4 Connections, Joints and Fasteners

Connections, joints and fasteners that are part of the seismic force-resisting system should be designed in accordance with AISI S100, except as modified in this Standard.

Tension or shear fracture, bolt shear, and block shear rupture are examples of limit states that generally result in non-ductile failure of connections. As such, these limit states are

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undesirable as the controlling limit state for connections that are part of the seismic force-resisting system. Accordingly, it is required that connections be configured such that a ductile limit state in the member or connection, such as yielding or bearing deformation, controls the available strength [factored resistance].

**E4.4.4.1 Bolted Joints**

This *Standard* prohibits the bolted joints being designed to share the load in combination with welds. Due to the potential of full load reversal and the likelihood of inelastic deformations in connecting elements, bolts may exceed their slip resistances under significant seismic loads. Welds that are in a common shear plane to these bolts will likely not deform sufficiently to allow the bolts to slip into bearing, particularly if subject to load reversal. Consequently, the welds will tend to resist the entire force and may fail if they were not designed as such.

The potential for full reversal of design load and the likelihood of inelastic deformations of members and/or connected parts necessitate that bolts in joints of the seismic force-resisting system be tightened to at least the snug-tight condition.

Earthquake motions are such that slip cannot and need not be prevented. To prevent excessive deformations of bolted joints due to slip between the connected plies under earthquake motions, the use of holes in bolted joints in the seismic force-resisting system is limited to standard holes and short-slotted holes with the direction of the slot perpendicular to the line of force.

**E4.4.4.1.1 Beam- to-Column Connections**

*Cold-Formed Steel* Special Bolted Moment Frame (CFS–SBMF) systems are comprised of cold-formed steel, single- or double-channel beams, and hollow structural section (HSS) columns. The beams and columns are connected by snug-tight high-strength bolts. Typical detail for this type of connection is shown in Figure C-E4.2-1.

Components of story drift due to the deformation of beam and column, and bolt slippage and bearing for a typical test specimen, are shown in Figure C-E4.4.4.1.1-1 (Hong and Uang, 2004). The inelastic deformation was mainly from the slip and bearing deformations of the bolted connection. By properly limiting the width-thickness ratios for both the beam and column, inelastic action in these members can be prevented.
E4.4.4.1.2 Bolt Bearing Plates

For relevant commentary on bolt bearing plates, see Section E4.3.1.2.

E4.4.4.2 Welded Joints

The general requirements for welded joints are given in AWS D1.1 (AWS, 2006) and AWS D1.3 (AWS, 1998), as applicable, wherein a Welding Procedure Specification (WPS) is required for all welds. When the typically thin elements of cold-formed structures in tension are joined by welding, it is almost always in single pass flare bevel welds. Many operations during fabrication, erection, and the subsequent work of other trades have the potential to create discontinuities in the seismic force-resisting system. When located in regions of potential inelasticity, such discontinuities should be repaired by the
responsible subcontractor. Discontinuities should also be repaired in other regions of the seismic force-resisting system when the presence of the discontinuity would be detrimental to the system performance. Repair may be unnecessary for some discontinuities.

**E4.4.4.3 Other Joints and Connections**

Alternative joints and connections are permitted by this Standard if they are justified by the professional engineer.

Alternative joints must, as a minimum, provide the same performance as the joints permitted by this Standard.
E5 Cold-Formed Steel Light Frame Shear Walls With Wood Structural Panel Sheathing on One Side and Gypsum Board Panel Sheathing on the Other Side

Shear walls with wood structural panels on one side and gypsum board panels on the other side are commonly employed in cold-formed steel framing. Limited testing has indicated that the presence of the gypsum board does alter the performance of the wall. In Canada: This may be accounted for by adding the additional capacity from the gypsum panel to the wood structural panel. In the United States and Mexico: No such provisions are specifically provided; instead, the presence of the gypsum board is implicit in the system overstrength and other seismic response factors.

This section is organized in a parallel format to that of Section E1. The commentary of Section E1 supplements the material presented here and should be reviewed for additional explanations.

E5.1 Scope

These provisions only apply in Canada. Appropriate seismic performance factors have not been determined in ASCE/SEI 7 for use in the United States and Mexico.

E5.2 Basis of Design

As provided in Section E1, shear walls with wood structural panels may be designed and detailed in such a way as to ensure a ductile failure mechanism at the sheathing-to-stud connection. Tilting and bearing of the connectors into the wood structural panel dissipates energy and is protected in the design of the system. When a gypsum board panel is added to the opposite side, the overall stiffness of the system increases and the gypsum board panel receives the same deformation history as the wood structural panel. Although gypsum board panels have a more brittle failure mechanism, they are deformation-controlled by the racking of the wall connected to the wood structural panel and thus, beneficial performance is possible. In this situation, both the connections from the wood structural panel and the gypsum board panel must be capacity-protected and are the designated energy-dissipating mechanism.

E5.3 Shear Resistance

Nominal resistance values for gypsum-sheathed walls were set at 80% of the values found in Table E6.3-1. This reduction in resistance level in Canada vs. the United States is similar to what is found for the wood sheathed walls of similar construction in Table E1.3-1.

E5.4 System Requirements

The system requirements are essentially the same as those of E1 (requirements a to r) with additional limitations related to the application of the gypsum board panel (s to u). For additional relevant commentary, see Section E1.4.
E6 Cold-Formed Steel Light Frame Shear Walls With Gypsum Board or Fiberboard Panel Sheathing

Shear walls with gypsum board or fiberboard panel sheathing have limited ductility, but due to the significant proportion of walls that may be sheathed with these materials, successful seismic performance is possible in some situations. Deformations at the stud-to-sheathing connections provide limited energy dissipation. In the United States and Mexico: This system is recognized, but with a relatively low R and limitations on its applicability in more stringent seismic design categories. In Canada: This system is not recognized as a separate seismic force-resisting system.

This section is organized in a parallel format to that of Section E1. The commentary of Section E1 supplements the material presented here and should be reviewed for additional explanations.

E6.1 Scope

These provisions only apply in the United States and Mexico. Appropriate seismic performance factors have not been determined in the NBCC.

E6.2 Basis of Design

The design basis for shear walls with gypsum board or fiberboard panels is similar to that of wood structural panels as fully discussed in Section E1. Although gypsum board and fiberboard panels have a more brittle failure mechanism than wood structural panels, satisfactory performance is possible. Tilting and bearing of the fasteners into the gypsum board or fiberboard provides limited energy dissipation and is the designated energy-dissipating mechanism for this type of wall.

The limited ductility is reflected in the seismic response factors employed, as summarized from ASCE/SEI 7-10 in Table C-E6.2.2.
### Table C-E6.2.2b

**United States and Mexico**

**Design Coefficients and Factors for Cold-Formed Steel Light Frame Shear Walls With Gypsum Board or Fiberboard Panel Sheathing**

<table>
<thead>
<tr>
<th>Basic Seismic Force-Resisting System ^b</th>
<th>Seismic Response Modification Coefficient, ( R )</th>
<th>System Over-strength Factor, ( \Omega_o ) ^c</th>
<th>Deflection Amplification Factor, ( C_d )</th>
<th>Structural System Limitations ^d and Building Height (ft) Limitations ^a</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. BEARING WALL SYSTEM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light-frame walls with shear panels of all other materials</td>
<td>2</td>
<td>2 ( \frac{1}{2} )</td>
<td>2</td>
<td>NL NL 35 NP NP</td>
</tr>
<tr>
<td><strong>A. BUILDING FRAME SYSTEM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light-frame walls with shear panels of all other materials</td>
<td>2 ( \frac{1}{2} )</td>
<td>2 ( \frac{1}{2} )</td>
<td>2 ( \frac{1}{2} )</td>
<td>NL NL 35 NP NP</td>
</tr>
</tbody>
</table>

\(^a\) NL = Not Limited and NP = Not Permitted.

\(^b\) Per ASCE/SEI 7 (ASCE, 2010), a bearing wall system is defined as a structural system with bearing walls providing support for all or major portions of the vertical loads. Per this Standard, braced frames are the basic seismic force-resisting elements.

\(^c\) The tabulated value of the overstrength factor, \( \Omega_o \), is permitted to be reduced by subtracting one-half for structures with flexible diaphragms, but shall not be taken as less than 2.0 for any structure.

\(^d\) See ASCE/SEI 7 (ASCE, 2010) Table 12.2-1 for additional footnotes.

For SI: 1 ft = 0.305 m

### E6.3 Shear Strength

The requirements for nominal strength of shear walls with gypsum board or fiberboard panel sheathing are comparable to those of shear walls with wood structural panel sheathing. Refer to Section E1.3.1, and also the following sections for additional commentary.

Strength of *Type I* shear walls with fiberboard panel sheathing are 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 E6.3-1 were based on monotonic tests of fiberboard sheathed, cold-formed steel framed shear walls and were compared to the monotonic and cyclic 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 E6.3-1 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: The upperbound estimate for expected strength introduced in Commentary Section B3.3 is also used for gypsum board and fiberboard shear walls. For these shear walls, per ASCE/SEI 7-10 with bearing wall systems, $\Omega_0 = 2.5$, and $\phi = 0.6$, results in an upperbound $\Omega_E = 1.5$.

E6.4 System Requirements

The system requirements are similar to those of Section E1 and additional relevant commentary is provided in Section E1.4. The provided requirements are more stringent than typically employed in conventional construction without seismic considerations (for example, in regions that are typically controlled by wind designs for the lateral force-resisting system). Engineers are cautioned that all requirements must be met for these systems to provide even the limited ductility that the applicable building code assigns to this system.

Currently, the shear wall deflection equations do not include provisions for gypsum board or fiberboard shear walls. However, the engineer 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 near to the elastic range of behavior.
E7 Conventional Construction Cold-Formed Steel Light Frame Strap Braced Wall Systems

In Canada: Seismic performance factors have been assigned for strap braced walls that are conventionally designed and detailed. That is, standard Limit States Design per CSA 136 is followed for all components and connections in the wall, but no special provisions are made to ensure ductility of the strap. The convenience of this approach is that a system that is conventionally designed for wind may be checked for seismic using the relatively low $R_dR_o$ that is provided by NBCC. In low seismic zones, the system may be adequate without modification.

In the United States and Mexico: Seismic performance factors similar to the NBCC do not exist for this specific system in ASCE/SEI 7. Instead, the general provisions for “Steel Systems not Specifically Detailed for Seismic Resistance” apply and $R=3$, but only Seismic Design Categories A, B, and C are permitted. Strap braced walls that have seismic detailing follow the provisions of Section E3 are permitted in higher seismic design categories.

E7.1 Scope

These provisions only apply in Canada. Appropriate seismic performance factors have not been determined in ASCE/SEI 7.

E7.2 Basis of Design

Conventional construction using the Limit States Design and following CSA 136 ensures that all possible limit states have an acceptable failure probability under monotonic loads. Connection limit states (e.g., fracture in the net section of the strap) use a higher reliability index than member limit states (e.g., strap yielding, chord stud buckling, etc.) and thus connections are expected to have a lower probability of failure than member limit states. The resulting conventional system has inherent ductility even without a designated energy-dissipating mechanism. These provisions recognize this inherent ductility and account for its use in design.

E7.3 Shear Resistance

The lateral shear resistance of the wall is determined by conventional design and is controlled by the governing limit state for all components and connections in the system. The strength expression in Section E3 is only applicable if yielding of the strap is the governing limit state—a condition that may be logical for preliminary design, and is certainly preferable from a ductile performance standpoint.

E7.4 System Requirements

Beyond conventional construction, this Standard requires that the straps be pre-tensioned and that the load transfer from the strap to the anchorages meet certain limitations in Section E3.4. This is required so that basic cyclic performance can be maintained in the system.
F. DIAPHRAGMS

F1 General

Diaphragms are the roof, floor or other membrane or bracing system that transfers in-plane forces to the vertical seismic force-resisting system; i.e., the walls. Since most seismic mass is located on the floors and roofs, the diaphragm has a special role in the transfer of inertial demands into the walls of a building (or vertical components of other structures). As a result, applicable building codes provide provisions related to the performance and design of floor diaphragms. Successful application of these provisions generally requires knowledge of the strength and stiffness of the diaphragm, quantities that this Standard provides guidance on.

F1.1 Scope

This Standard permits the use of steel sheet sheathing, concrete or wood structural panels or other approved materials to serve as the diaphragm sheathing. However, prescriptive provisions are only provided for cold-formed steel framing with wood structural panels.

This 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 of the Standard.

F1.2 Design Basis

Current design of diaphragms (e.g., ASCE/SEI 7-10) does not associate energy dissipation with the diaphragm nor tie specific diaphragm systems to specific seismic force-resisting systems. Although evidence is growing that the diaphragm can have a significant impact on the overstrength and ductility of the complete lateral force-resisting system, currently this is not part of the design basis for diaphragms.

Diaphragms should have an available strength that is greater than or equal to the required strength from the applicable building code. In addition, diaphragm stiffness is often needed to determine if the diaphragm is rigid, flexible, or semi-rigid. This stiffness distinction is important for understanding how torsional forces develop in the building (or other structure) and how the torsion forces are (or are not) distributed to the vertical seismic force-resisting systems.

Diaphragms that dissipate energy are an area of new research, and it is anticipated that future versions of this Standard will provide guidance on capacity-based design and the role of energy dissipation and overstrength in diaphragms.

F1.3 Required Strength

The required strength of the seismic force-resisting systems of Chapter E are influenced by the diaphragm stiffness—i.e., flexible diaphragms do not have to consider direction torsion, while rigid diaphragms must include in-plane torsion effects resulting from differences in the center of mass and center of stiffness as detailed in the applicable building code. It is also possible that a condition between the rigid and flexible extremes (semi-rigid) must be considered for the diaphragm. Given uncertainty and complication with determining diaphragm stiffness, the User Note provides guidance on a conservative approach in common use in current practice: check both rigid and flexible diaphragm conditions and take the worst-case loads for the required strength on the seismic force-resisting systems.
For cold-formed steel framed diaphragms with wood structural panels, this Standard provides explicit provisions for stiffness. For all other diaphragms, the applicable building code or rational engineering analysis is required.

The required strength of chords, collectors and other components and connections in the diaphragm is addressed within the applicable building code and within the seismic force-resisting systems detailed in Chapter E.

**F1.4 Shear Strength**

The Standard provides limited guidance on determining the nominal in-plane shear strength of diaphragms and defers to engineering analysis. An exception to this is cold-formed steel framed diaphragms with wood structural panels, which are handled explicitly in Section F2. In addition, for profiled steel diaphragms, AISI 310 (AISI, 2013) is appropriate. For all other diaphragms, the nominal strength should be determined by engineering analysis appropriate to the potential limit states of the diaphragm. The available strength depends on the limit state and in general should follow the reliability principles outlined in AISI S100 (AISI, 2012) Chapter F.

**F2 Cold-Formed Steel Diaphragms Sheathed With Wood Structural Panels**

**F2.1 Scope**

See AISI S240 Section B5.4.2.3 for additional discussion.

**F2.2 Additional Design Requirements**

Since the diaphragm does have an impact on the overall seismic lateral force-resisting system, the Standard recognizes two classes of detailing: conventional and seismic. Conventional detailing is allowed for R≤3 structures, while seismic detailing (per Standard Section F2.5) is required for R>3 systems. The seismic detailing requirements of Standard Section F2.5 are not extensive and the engineer is encouraged to meet these requirements even for conventional construction.

**F2.3 Required Strength**

[Reserved]

**F2.4 Shear Strength**

**F2.4.1 Nominal Strength**

For diaphragms sheathed with wood structural panels, the nominal strength may be determined by Table F2.4-1 which is 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). Since 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 lb 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 lb 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 lb, 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-F2.4.1-1 below, 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>
<thead>
<tr>
<th>No. 8 Screw Shear Strength (lb) for 33-mil Cold-Formed Steel Member</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lum</td>
</tr>
<tr>
<td>Nominal</td>
</tr>
<tr>
<td>372</td>
</tr>
</tbody>
</table>

F2.4.2 Available Strength

The safety and resistance factors employed are based on engineering judgment in comparison with steel diaphragms from AISI S100 (AISI, 2012) at the time of the creation of the first edition of AISI S213 (AISI, 2007b), a precursor to this Standard.

F2.4.3 Design Deflection

Deflection expressions are provided in AISI S240 Section B5.4.4.1 and are repeated here for convenience. The deflection of a blocked diaphragm sheathed with wood structural panels is permitted to be determined in accordance with the following:

\[
\delta = \frac{0.052 v L^3}{E_s A_c b} + \frac{v L}{\rho G t_{\text{sheathing}}} + \left(\frac{v}{2\beta}\right)^2 \sum_{j=1}^{n} \frac{\Delta c_i X_i}{2b}
\]

(Eq. C-F2.4.3-1)

where

\( A_c \) = Gross cross-sectional area of chord member, in² (mm²)
\( b \) = Diaphragm depth parallel to direction of load, in. (mm)
\( E_s \) = Modulus of elasticity of steel
\( = 29,500,000 \text{ psi} \) (203,000 MPa)
\( G \) = Shear modulus of sheathing material, in lb/in² (MPa)
L = Diaphragm length perpendicular to direction of load, in. (mm)
n = Number of chord splices in diaphragm (considering both diaphragm chords)
s = Maximum fastener spacing at panel edges, in. (mm)
t_{sheathing} = Nominal panel thickness, in. (mm)
t_{stud} = Nominal stud thickness, in. (mm)
v = Shear demand, in lb/in. (N/mm)\n= V/(2b) \hspace{1cm} (Eq. C-F2.4.3-2)
V = Total lateral load applied to the diaphragm, in lb (N)
X_i = Distance between the “ith” chord-splice and the nearest support (braced wall line), in. (mm)
α = 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)
β = 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}).
δ = Calculated deflection, in in. (mm)
Δ_{ci} = Deformation value associated with “ith” chord splice, in in. (mm)
ρ = 1.85 for plywood other than CSP
= 1.05 for OSB and CSP
ω_1 = s/6 \hspace{1cm} (for s in in.)
= s/152.4 \hspace{1cm} (for s in mm) \hspace{1cm} (Eq. C-F2.4.3-3a)
ω_2 = 0.033/t_{stud} \hspace{1cm} (for t_{stud} in in.)
= 0.838/t_{stud} \hspace{1cm} (for t_{stud} in mm) \hspace{1cm} (Eq. C-F2.4.3-4a)

The above equation applies 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 β and ρ in deflection Equation C-E2.4.3-1 were revised based on research work by Cobeen (2010). Based on shear wall performance, similar revisions were made to the deflection Equation C-F2.4.3-1 for the diaphragm systems.

**F2.5 Requirements Where Seismic Response Modification Coefficient, R, Greater Than Three**

To limit torsion, this Standard limits application to open front structures. Also, to avoid narrow panels that are unable to develop adequate shear behavior due to their aspect ratio, a minimum panel width is required.

**F3 Other Diaphragms**

[Reserved]
G. QUALITY CONTROL AND QUALITY ASSURANCE

For relevant commentary on quality control and quality assurance for the seismic force-resisting systems in this Standard, see Chapter D of AISI S240 and AISI 220, Code of Standard Practice for Cold-Formed Steel Framing. All seismic force-resisting systems in this Standard have detailed system requirements to ensure the system can provide the necessary ductility and assumed overstrength. In some cases the system requirements depart from conventional construction; particularly, for regions that are not commonly controlled by seismic design. For example, chord studs on shear walls are critical components that must not be modified, even if providing double duty as a jamb for an opening in addition to a chord stud. Also, the requirement that all fasteners be driven flush is a unique requirement and underlines the care that should be taken in constructing seismic force-resisting systems. Even though in many cases the seismic-force resisting system does not visually appear drastically different from a conventional gravity wall, it is different in function and necessity for the engineering system, and it is important that actual system requirements of this Standard be enforced during construction.

Additional quality assurance and quality control procedures are provided for the Cold-Formed Steel Special Bolted Moment Frame (CFS-SBMF) system of Section E4, which is unique to seismic design. Snug-tightened bolts are specified, as is customary for this type of construction. However, a departure from traditional practice is to require that the bolt tightness be checked on a representative sample of bolts. This is because a modest level of tightness is required to develop the expected level of slip resistance in the connections. An ordinary spud wrench is used to make this check. It should be noted that fully pretensioned bolts, such as is required in slip-critical connections in heavier construction, are not suitable for cold-formed steel structural systems. The higher levels of tensioning for those applications are usually controlled by the turn-of-nut method, but the rotations specified are not applicable to cold-formed steel because they are based on greater grip lengths than those typically encountered with the thinner material. The turn-of-nut and other methods are outlined by the Research Council on Structural Connections.
H. USE OF SUBSTITUTE COMPONENTS AND CONNECTIONS IN SEISMIC FORCE-RESISTING SYSTEMS

For a number of years, evaluation services have issued product evaluation reports that advised building officials that specific manufactured products were acceptable as substitutes for structural components comprising portions of seismic force-resisting systems with specific code-specified design and detailing criteria. These evaluation service reports were typically based on a comparison of hysteretic test data for the proposed product and also for limited sets of available data on the performance of code-conforming systems. Such evaluation service reports have been issued for special steel moment resisting connections, proprietary shear wall products intended for use in light frame construction, and other technologies.

While the evaluation services have attempted to perform impartial and meaningful evaluations of the effect of component substitution on system response, there has not been any consensus basis as to appropriate means of judging the adequacy of a substitute component’s performance capability or the bounds under which its use should be permitted. Recently, FEMA P795 (2011) was published. This methodology uses an extensive database on the effects of changes in certain hysteretic response parameters, including stiffness, peak strength and ultimate deformation capacity, on overall system response and collapse resistance. The methodology then applies statistical methods to characterize the ability of structures incorporating the substitute components to apply equivalent or better resistance to collapse than structures incorporating code-specified components, considering uncertainties associated with the quantity and quality of available laboratory test data used to characterize the performance of conforming and substitute components. This methodology is deemed to comprise a preferred means of demonstrating the acceptability of component substitution in the structural systems covered in this Standard.
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APPENDIX 1, SEISMIC FORCE MODIFICATION FACTORS AND LIMITATIONS IN CANADA

NBCC adoption cycles do not always allow for the latest research to be incorporated. Therefore, for solutions not yet incorporated into NBCC, this section provides additional guidance on seismic force modification factors. These values are only intended for use in Canada, and only when the NBCC does not contain such values.
REFERENCES


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Hong, J.K. and C.M. Uang (2004), “Cyclic Testing of Cold-Formed Steel Moment Connection for Pre-Fabricated Mezzanines,” Report No. TR-04/03, University of California, San Diego, La Jolla, CA.


Rack Manufacturers Institute (2004), Specification for the Design, Testing and Utilization of Industrial Steel Storage Racks, Charlotte, NC.


Advisory Note: The Light Gauge Steel Engineers Association (LGSEA) changed its name to the Cold-Formed Steel Engineers Institute (CFSEI) in 2006.