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North American Standard for Cold-Formed Steel Framing -- Wall Stud Design, 2007 Edition (Reaffirmed 2012)

American Iron and Steel Institute

AISI S211—07 (2012)

American Iron and Steel Institute

AISI STANDARD

North American Standard for Cold-Formed Steel Framing— Wall Stud Design

2007 Edition (Reaffirmed 2012)

Revision of AISI/COFS/WSD - 2004

Endorsed by

Steel Framing Alliance™

DISCLAIMER

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

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

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

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PREFACE

The American Iron and Steel Institute Committee on Framing Standards has developed AISI S211, the *North American Standard for Cold-Formed Steel Framing – Wall Stud Design*, to provide technical information and specifications for designing wall *studs* made from cold-formed steel. This standard is intended for adoption and use in the United States, Canada and Mexico.

This standard provides an integrated treatment of Allowable Strength Design (ASD), Load and Resistance Factor Design (LRFD), and Limit States Design (LSD). This is accomplished by including the appropriate resistance factors (ϕ) for use with LRFD and LSD, and the appropriate factors of safety (Ω) for use with ASD. It should be noted that LSD is limited to Canada and LRFD and ASD are limited to Mexico and the United States.

The Committee acknowledges and is grateful for the contributions of the numerous engineers, researchers, producers and others who have contributed to the body of knowledge on the subjects. The Committee wishes to also express their appreciation for the support of the Steel Framing Alliance and the Canadian Sheet Steel Building Institute.

In this 3rd printing edition, the errata distributed on July 24, 2015 and August 15, 2016 were incorporated as shown in the tracked changes.

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NORTH AMERICAN STANDARD FOR COLD-FORMED STEEL FRAMING – WALL STUD DESIGN

A. GENERAL

A1 Scope

The design and installation of *cold-formed steel studs* for structural walls in buildings shall be in accordance with AISI S100 [CSA S136] and AISI S200, except as modified by the provisions of this standard. Alternatively, *cold-formed steel studs* for structural walls in buildings shall be permitted to be designed solely in accordance with AISI S100 [CSA S136].

This standard shall 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.

This standard shall include Sections A through C in their entirety.

A2 Definitions

Where terms appear in this standard in italics, such terms shall have meaning as defined in AISI S200. Terms included in square brackets are specific to *LSD* terminology. Terms not italicized shall have the ordinary accepted meaning in the context for which they are intended.

A3 Loads and Load Combinations

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

A3.1 Wind Loading Considerations in the United States and Mexico

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

(a) Combined bending and axial strength based on Main Wind Force Resisting System (MWFRS) wind loads.

(b) Bending strength based on Components and Cladding (C&C) wind loads.

(c) Deflection limits based on ~~70~~42% of Components and Cladding (C&C) wind loads with no axial loads.

A4 Referenced Documents

The following documents or portions thereof are referenced in this standard and shall be considered part of the requirements of this document.

1. AISI S100-12, *North American Specification for the Design of Cold-Formed Steel Structural Members,* American Iron and Steel Institute, Washington, DC.
2. AISI S200-12, *North American Standard for Cold-Formed Steel Framing – General Provisions*, American Iron and Steel Institute, Washington, DC.
3. ASCE 7-10 Including Supplement 1, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, VA.
4. CAN/CSA S136-07-12, *North American Specification for the Design of Cold-Formed Steel Structural Members*, Canadian Standards Association, Mississauga, Ontario, Canada.
5. NBCC 2010, *National Building Code of Canada*, 2005 Edition, National Research Council of Canada, Ottawa, Ontario, Canada.

B. DESIGN

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

B1 Member Design

Wall *studs* shall be designed either on the basis of an all steel design or on the basis of sheathing braced design. *Webs* shall be solid or have holes that satisfy AISI S100 [CSA S136].

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

(b) Sheathing Braced Design. Wall *stud* assemblies using a sheathing braced design shall be designed assuming that identical sheathing is attached to both sides of the wall *stud* and connected to the bottom and top horizontal members of the wall to provide lateral and torsional support to the wall *stud* in the plane of the wall. Wall *studs* with sheathing attached to both sides that is not identical shall be designed based on the assumption that the weaker of the two sheathings is attached to both sides.

When sheathing braced design is used, the engineering drawings shall identify the sheathing as a structural element.

In the United States and Mexico: When sheathing braced design is used, the wall *studs* shall be evaluated without the sheathing *bracing* for the following load combination:

$$1.2D + (0.5L \text{ or } 0.2S) + 0.2W \qquad (Eq.\ B1\text{-}1)$$

Where:
D = Dead load
L = Live load
S = Snow load
W = Wind load

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

B1.1 Properties of Sections

The properties of sections shall be determined in accordance with conventional methods of structural design. Properties shall be full cross section properties, except where use of a reduced cross section or effective design width is required by AISI S100 [CSA S136].

B1.2 Axial Load

Both ends of the *stud* shall be connected to restrain rotation about the longitudinal stud axis and horizontal displacement perpendicular to the *stud* axis.

(a) For all steel design of wall *studs* in compression, Section C4 and D4(a) of AISI S100 [CSA S136] shall define the axial strength [resistance]. The effective length, KL, shall be determined by rational analysis and/or testing, or in the absence of such analysis or tests, K_x,

K_y and K_t shall be taken as unity. The unbraced length with respect to the major axis, L_x, shall be taken as the distance between end supports of the member, while unbraced lengths L_y and L_t shall be taken as the distance between braces.

(b) For sheathing braced design of wall *studs* in compression, the axial strength [resistance] shall be determined in accordance with the provisions of this section.

The axial strength [resistance] shall be calculated using Section C4 of AISI S100 [CSA S136]. The unbraced length with respect to the major axis, L_x, shall be taken as the distance between end supports of the member. The unbraced length with respect to the minor axis, L_y, and the unbraced length for torsion, L_t, shall be taken as twice the distance between sheathing connectors. The buckling coefficients K_x, K_y, and K_t shall be taken as unity.

To prevent failure of the sheathing-to-wall *stud* connection, where identical gypsum sheathing is attached to both sides of the wall *stud* with screws spaced at a maximum of 12 inches (305 mm) on center, the maximum axial *nominal load* [*specified load*] in the wall *stud* shall be limited to the values given in Table B1-1.

Table B1-1
Maximum Axial Nominal Load [Specified Load]
Limited by Gypsum Sheathing-to-Wall Stud Connection Capacity

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

B1.3 Bending

For all steel design, Section C3.1.2.1 of AISI S100 [CSA S136] shall define the flexural strength [resistance].

For sheathing braced design, and neglecting any rotational restraint provided by the sheathing, Section C3.1.1 of AISI S100 [CSA S136] shall define the design flexural strength [resistance].

B1.4 Shear

For either all steel design or sheathing braced design, the design shear strength [resistance] shall be defined by Section C3.2 of AISI S100 [CSA S136].

B1.5 Axial Load and Bending

For either all steel design or sheathing braced design, the required axial strength [resistance] and flexural strength [resistance] shall satisfy the interaction equations of Section C5 of AISI S100 [CSA S136].

B1.6 Web Crippling

For either all-steel design or sheathing braced design, the web crippling strength [resistance] alone, P_n, shall be determined by using Section C3.4 of AISI S100 [CSA S136], or P_n shall be modified in accordance with Section B2.2 of this standard for the increased strength due to the *track*.

B1.7 Built-up Sections

For either all steel design or sheathing braced design, the design strength [resistance] of built-up sections shall be defined by Section C4.5 of AISI S100 [CSA S136]. When the connection requirements of AISI S100 [CSA S136] are not met, the design strength [resistance] of built-up sections shall be equal to the sum of the design strengths [resistances] of the individual members of the built-up cross section.

B2 Connection Design

B2.1 Fastening Methods

Screw, bolt, and weld connections shall be designed in accordance with AISI S100 [CSA S136] and AISI S200. For connections using other fastener types, design values [factored resistances] shall be determined by testing in accordance with Section F1 of AISI S100 [CSA S136].

B2.2 Stud-to-Track Connection for C-Section Studs

The *stud*-to-*track* connection shall satisfy the requirements for web crippling strength [resistance] of the *stud*, in accordance with sections B1.6 and C1 of this standard, or as defined in this section.

(a) For *curtain wall studs* that are not adjacent to wall openings and where both *stud flanges* are connected to the *track flanges* and the *track* thickness is greater than or equal to the *stud* thickness, the nominal strength [resistance], P_{nst}, shall be determined in accordance with Eq. B2.2-1, as follows:

$$P_{nst} = Ct^2F_y\left(1 - C_R\sqrt{\frac{R}{t}}\right)\left(1 + C_N\sqrt{\frac{N}{t}}\right)\left(1 - C_h\sqrt{\frac{h}{t}}\right) \qquad (Eq.\ B2.2\text{-}1)$$

Where:

C	=	web crippling coefficient = 3.7
C_R	=	inside bend radius coefficient = 0.19
C_N	=	bearing length coefficient = 0.74
C_h	=	web slenderness coefficient = 0.019
R	=	stud inside bend radius
N	=	stud bearing length
h	=	depth of flat portion of stud web measured along plane of web
t	=	stud design thickness
Ω	=	1.70 for ASD
ϕ	=	0.90 for LRFD
	=	0.75 for LSD

The above equation shall be valid within the following range of parameters:

Screw Size: No. 8 minimum

<u>Stud Section</u>
Design Thickness: 0.0346 inch to 0.0770 inch (0.88 mm to 1.96 mm)
Design Yield Strength: 33 ksi to 50 ksi (228 MPa to 345 MPa)
Nominal Depth: 3.50 inch to 6.0 inch (88.9 mm to 152.4 mm)

Track Section

Design Thickness:	0.0346 inch to 0.0770 inch (0.88 mm to 1.96 mm)
Design Yield Strength:	33 ksi to 50 ksi (228 MPa to 345 MPa)
Nominal Depth:	3.50 inch to 6.0 inch (88.9 mm to 152.4 mm)
Nominal Flange Width:	1.25 inch to 2.375 inch (31.8 mm to 60.3 mm)

(b) For *curtain wall studs* that are not adjacent to wall openings and where both *stud flanges* are connected to the *track flanges* and the *track* thickness is less than the *stud* thickness, the nominal strength [resistance], P_{nst}, shall be the lesser of Equations B2.2-1 or B2.2-2, which is defined as follows:

$$P_{nst} = 0.6\, t_t\, w_{st}\, F_{ut} \qquad (Eq.\ B2.2\text{-}2)$$

Where:

t_t	=	design *track* thickness
w_{st}	=	$20\, t_t + 0.56\alpha$
α	=	coefficient for conversion of units
	=	1.0 when t_t is in inches
	=	25.4 when t_t is in mm
F_{ut}	=	tensile strength of the *track*
P_{nst}	=	nominal strength for the *stud*-to-*track* connection when subjected to transverse loads
Ω	=	1.70 for ASD
ϕ	=	0.90 for LRFD
	=	0.80 for LSD

The above equation shall be valid within the following range of parameters:

Screw Size: No. 8 minimum

Stud Section

Design Thickness:	0.0346 inch to 0.0770 inch (0.88 mm to 1.96 mm)
Design Yield Strength:	33 ksi to 50 ksi (228 MPa to 345 MPa)
Nominal Depth:	3.50 inch to 6.0 inch (88.9 mm to 152.4 mm)

Track Section

Design Thickness:	0.0346 inch to 0.0770 inch (0.88 mm to 1.96 mm)
Design Yield Strength:	33 ksi to 50 ksi (228 MPa to 345 MPa)
Nominal Depth:	3.50 inch to 6.0 inch (88.9 mm to 152.4 mm)
Nominal Flange Width:	1.25 inch to 2.375 inch (31.8 mm to 60.3 mm)

(c) For *curtain wall studs* that are adjacent to wall openings and where both *stud flanges* are connected to the *track flanges* and the track terminates at the opening, the nominal strength [resistance] shall be taken as 0.5 P_{nst} using P_{nst}, Ω and ϕ, as determined in accordance with Section B2.2(a) where the *track* thickness is greater than or equal to the *stud* thickness or Section B2.2(b) where the *track* thickness is less than the *stud* thickness.

(d) For *curtain wall studs* that are not adjacent to wall openings and do not have both *stud flanges* connected to the *track flanges* and the *track* thickness is greater than or equal to the *stud* thickness, nominal strength [resistance], P_{nst} shall equal P_n, along with Ω and ϕ, as determined by Section C3.4.1 of AISI S100 [CSA S136].

(e) For *curtain wall studs* that are adjacent to wall openings and do not have both *stud flanges* connected to the *track flanges* and the *track* thickness is greater than or equal to the *stud* thickness, nominal strength [resistance], P_{nst} shall equal $0.5P_n$, along with Ω and ϕ, as determined by Section C3.4.1 of AISI S100 [CSA S136].

B2.3 Deflection Track Connection for C-Section Studs

For *curtain wall studs* used in *deflection track* connections P_{nst} shall equal P_n, along with Ω and ϕ, as determined by Section C3.4.1 of AISI S100 [CSA S136]. The bearing length used in these calculations shall not exceed the minimum engagement between the *stud* and the *track* or 1 inch (25.4 mm).

The *nominal strength* [resistance] of a single *deflection track* subjected to transverse loads and connected to its support at a fastener spacing not greater than the *stud* spacing shall be determined in accordance with Eq. B2.3-1, as follows:

$$P_{ndt} = \frac{w_{dt} t^2 F_y}{4e} \qquad (Eq.\ B2.3\text{-}1)$$

Where:

w_{dt}	=	effective track length = $0.11(\alpha^2)(e^{0.5}/t^{1.5}) + 5.5\alpha \le S$
S	=	center-to-center spacing of studs
t	=	*track* design thickness
F_y	=	design yield strength of *track* material
e	=	design end or slip gap (distance between *stud web* at end of *stud* and *track web*)
α	=	coefficient for conversion of units
	=	1.0 when e, t and S are in inches
	=	25.4 when e, t and S are in mm
Ω	=	2.80 for ASD
ϕ	=	0.55 for LRFD
	=	0.45 for LSD

The above equation shall be valid within the following range of parameters:

<u>Stud Section</u>

Design Thickness:	0.0451 inch to 0.0713 inch (1.14 mm to 1.81 mm)
Design Yield Strength:	33 ksi to 50 ksi (228 MPa to 345 MPa)
Nominal Depth:	3.50 inch to 6.0 inch (88.9 mm to 152.4 mm)
Nominal Flange Width:	1.625 inch to 2.5 inch (41.3 mm to 63.5 mm)
Stud Spacing:	12 inch to 24 inch (305 mm to 610 mm) on center
Stud Bearing Length:	¾ inch (19.1 mm) minimum

<u>Track Section</u>

Design Thickness:	0.0451 inch to 0.0713 inch (1.14 mm to 1.81 mm)
Design Yield Strength:	33 ksi to 50 ksi (228 MPa to 345 MPa)
Nominal Depth:	3.50 inch to 6.0 inch (88.9 mm to 152.4 mm)
Nominal Flange Width:	2.00 inch to 3.00 inch (50.8 mm to 76.3 mm)

The horizontal distance from the *web* side of the *stud* to the terminating end of the *track* shall not be less than one half the effective *track* length w_{dt}.

B3 Bracing

B3.1 Intermediate Brace Design

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

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

For combined bending and axial loads, each intermediate brace shall be designed for the combined brace force determined in accordance with Section D3.2.2 of AISI S100 [CSA S136] and 2% of the design compression force in the member.

B4 Serviceability

Serviceability limits shall be chosen based on the intended function of the wall system, and shall be evaluated using load and load combinations in accordance with Section A3 of this standard.

C. INSTALLATION

Wall *studs* shall be installed in accordance with AISI S200 and the requirements of this section.

C1 Stud-to-Track Connection

The *stud flange* shall engage the *track flange* sufficiently to meet the requirements of Section B2.2 of this standard and to permit both ends of the wall *stud* to be properly connected to the *track* to restrain rotation about the longitudinal wall *stud* axis and horizontal displacement perpendicular to the wall *stud* axis. Further, for structural walls, the maximum gap between the end of the *stud* and the *track web* shall also comply with Section C32.4.4 of AISI S200.

For *curtain walls*, the ends of the wall *studs* shall be seated squarely in the *track* with no more than a ¼ inch (6.4 mm) gap between the end of the wall *stud* and the *track*, unless otherwise specified in an *approved* design.

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PREFACE

This *Commentary* is intended to facilitate the use, and provide an understanding of the background, of AISI S211, the *North American Standard for Cold-Formed Steel Framing – Wall Stud Design*. The *Commentary* illustrates the substance and limitations of the various provisions of the standard.

In the *Commentary*, sections, equations, figures, and tables are identified by the same notation as used in the standard. Words that are italicized are defined in AISI S200. Terms included in square brackets are specific to LSD terminology.

In this 3rd printing edition, the errata distributed on July 24, 2015 were incorporated as shown in the tracked changes.

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COMMENTARY ON THE
NORTH AMERICAN STANDARD FOR COLD-FORMED STEEL FRAMING –
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COMMENTARY ON THE NORTH AMERICAN STANDARD FOR COLD-FORMED STEEL FRAMING – WALL STUD DESIGN

A. GENERAL

A1 Scope

AISI S211 (AISI, 2012c) applies to the design and installation of *cold-formed steel studs* for structural walls in buildings and provides a supplement to AISI S100 [CSA S136], (AISI, 2012a; CSA, 2012).

Prior to 2012, AISI S211 included provisions for both structural and nonstructural walls. In 2012, provisions related to *nonstructural member* design are covered by AISI S220, *North American Standard for Cold-Formed Steel Framing - Nonstructural Members*.

A3 Loads and Load Combinations

Currently, *ASCE 7* (ASCE, 2010) has no geographical-based information on Mexico. Therefore, users with projects in Mexico should work with the appropriate authority having jurisdiction to determine appropriate loads and load combinations that are consistent with the assumptions and rationale used by *ASCE 7*.

The 42% is applied the ultimate Component and Cladding (C&C) wind *load*, without any additional applied *load* combination factors. The 0.42 (i.e. 42%) replaces the basic *load* factor in the *load* combination.

A3.1 Wind Loading Considerations in the United States and Mexico

Because a wall *stud* subject to combined bending and axial load resists wind loads imposed on two surfaces, the member can be analyzed based on Main Wind Force Resisting System (MWFRS) wind loads. For bending alone, the wall *stud* experiences wind from only one surface and therefore must be analyzed for Components and Cladding (C&C) wind loads.

Section 1609.6.2.3 of the International Building Code (ICC, 2003) states that:

> *"Members that act as both part of the main force resisting system and as components and cladding shall be designed for each separate load case."*

Discussion in the Southern Building Code Commentary (SBCCI, 1999) sheds light on a reasonable approach to the design of wall *studs* for wind resistance, stating that:

> *"Some elements of a building will function as part of the main wind force resisting system and components and cladding also. Such members include but not limited to roof panels, rafters, and wall studs. These elements are required to be designed using the loads that would occur by considering the element as part main wind force resisting system, and also separately checked or designed for loads that would occur by considering the element as component and cladding. The use of this section can be demonstrated by considering, for example, the design of a wall stud. When designing the stud for main wind force resisting system loads, all loads such as bending from the lateral force with the wind on the wall in addition to any uplift in combinations with the dead load of the roof or a story above induced by the simultaneous action of roof forces should be considered together. When designing the*

> *stud for component and cladding loads, only the bending resulting from the wind force normal to the stud and the dead load associated with that member should be considered. The member should be sized according to the more critical loading condition."*

The wood industry has also investigated this condition and has adopted a similar policy as shown in the Wood Frame Construction Manual (AFPA, 1995) where section 2.4 states that:

> *"Studs tables are based upon bending stresses induces by C&C Loads. The bending stresses are computed independent of axial stresses. In addition, the case in which bending stresses from MWFRS loads act in combination with axial stresses from wind and gravity loads have been analyzed. For buildings limited to the conditions in the WFCM-SBC, the C&C loads control stud design."*

The Commentary to Appendix C of *ASCE* 7 (ASCE, 2010) provides some guidance on the selection of loads for checking the serviceability limit state of buildings and their components where Section B1.2 states in part:

> *"Use of factored wind load in checking serviceability is excessively conservative. The load combination with an annual probability of 0.05 of being exceeded, which can be used in checking short-term effects, is* $D + 0.5L + 0.7W$*."*

Thus using 70% of the wind load from Components and Cladding for checking deflections should conservatively satisfy the above.

AISC Design Guide No. 3 (Fisher and West, 1990) also recommends reduced wind loads when checking the serviceability of cladding based upon a 10-year return period or 75 percent of the 50-year wind pressure.

B. DESIGN

B1 Member Design

The standard permits the design of wall *studs* to be based on either an all steel design in which discrete braces are provide along the member's length, or based on a sheathing braced design.

The standard stipulates that when sheathing braced design is used, the wall *stud* shall be evaluated without the sheathing *bracing* for the dead loads and loads that may occur during construction or in the event that the sheathing has been removed or has accidentally become ineffective. The LRFD load combination for the United States and Mexico is taken from *ASCE* 7 (ASCE, 2010) for special event loading conditions.

Although the design approach for sheathing braced design is based upon engineering principals, the standard limits the sheathing braced design to wall *stud* assemblies assuming that identical sheathing is attached to both sides of the wall *stud*. This limit recognizes that identical sheathing will aid in minimizing the twisting of the section. If only single sided sheathing is used, additional twisting of the section will occur thus placing a greater demand on the sheathing; therefore, the *stud* must be designed and braced as an all steel assembly.

The provision that wall *studs* with sheathing attached to both sides that is not identical shall be permitted to be designed based on the assumption that the weaker of the two sheathings is attached to both sides is based on engineering judgment. Determination of which of the two sheathings is weaker shall consider the sheathing strength, sheathing stiffness and sheathing-to-wall *stud* connection capacity, as applicable.

B1.2 Axial Load

Prior to 2004, the *North American Specification for the Design of Cold-Formed Steel Structural Members* contained requirements for sheathing braced design in its Section D4(b). In 2004, these provisions were removed. AISI S100 [CSA S136], (AISI, 2012a; CSA, 2012) now permits sheathing braced design in accordance with an appropriate theory, tests, or rational engineering analysis.

Sheathing braced design in the standard is based on rational analysis assuming that the sheathing braces the *stud* at the location of each sheathing-to-*stud* fastener location. Axial load in the *stud* is limited, therefore, by the capacity of the sheathing or sheathing-to-wall *stud* connection. Using the bracing principles as defined by Winter (1960) and summarized by Salmon and Johnson (1996) in which the brace force is given as follows:

$$F_{br} = K (\Delta + \Delta_o) = 0.02 P \qquad (Eq.\ B1\text{-}2)$$

Where:

$\Delta = \Delta_o = L/384$

L = total stud height

$K = 4P/L$

The limit of L/384 is based on the maximum bow of 1/32 inch/foot (2.6 mm/m) as prescribed by Table A5.1 of AISI S200 (AISI, 2012b). The tests indicated a failure of the sheathing, not the screw-to-stud attachment. Thus, the standard does not directly stipulate a design requirement to check the screw-to-stud capacity or the screw capacity in shear.

The strength of gypsum sheathing attached with No. 8 and No. 6 screws is based on tests by Miller (1989) and Lee (1995), respectively. Based on engineering judgment, a factor of safety of 2.0 was applied to the ultimate load when determining the maximum nominal [specified] load for the gypsum wallboard. The ultimate loads are based on the averaging of test data provided in Miller (1989) and Lee (1995).

Table B1-1
Maximum Axial Nominal Load [Specified Load]
Limited by Gypsum Sheathing-to-Wall Stud Connection Capacity

Sheathing	Screw Size	Ultimate Load (per screw)	Maximum Nominal [Specified] Load (per screw)
1/2 inch (12.7 mm)	No. 6	0.117 kips (0.516 kN)	0.058 kips (0.258 kN)
1/2 inch (12.7 mm	No. 8	0.134 kips (0.596 kN)	0.067 kips (0.298 kN)
5/8 inch (15.9 mm)	No. 6	0.136 kips (0.605 kN)	0.068 kips (0.302 kN)
5/8 inch (15.9 mm)	No. 8	0.156 kips (0.694 kN)	0.078 kips (0.347 kN)

The unbraced length with respect to the minor axis and the unbraced length for torsion are taken as twice the distance between the sheathing connectors in the event that an occasional attachment is defective to a degree that it is completely inoperative.

If plywood sheathing is attached to both *flanges* of the wall *stud* by screws spaced no greater than 12 inches (305 mm) on center, both the plywood and the *stud* must be checked. The following outlines a possible design solution for plywood attached to a wall *stud*:

Evaluation of the Plywood:

Using NDS (AFPA, 1997) Section 11.3,

Nominal Design Value, $Z = D\, l_m\, F_{em}/R_d$

D = 0.164″ (No. 8 Screw)

l_m = sheathing thickness = 0.5″

$R_d = 2.2$ for $D \leq 0.17''$

F_{em} = 1900 psi (lowest bearing strength value – the values are based on the specific gravity of the wood)

Z = 0.164 x 0.5 x 1900 / 2.2 = 70.82 lbs.

Brace Force, $F_{br} = 0.02\, P$, where P is the axial load in the *stud*.

P = 70.82/0.02 = 3,540 lbs = 3.5 kips per screw x 2 screws = 7.0 kips per *stud*

Evaluation of the Steel Wall *Stud*:

The screw capacity in the *stud* can be evaluated using Section E4.3 of the *Specification*, where:

$P_{ns} = 4.2\, (t^3 d)^{0.5}\, F_u \leq 2.7\, tdF_u$

$\Omega = 3.0$

If $P_{ns}/\Omega < Z$, the brace force analysis to determine P should be based on the lower value. The capacity per screw is computed by the following equation.

$P = (P_{ns}/\Omega < Z)/0.02$

Because the standard requires that sheathing must be attached to both *flanges* of the wall *stud*, the *nominal* axial load in the wall *stud* is twice the value of P.

B2 Connection Design

B2.1 Fastening Methods

Self-drilling screws are the primary fastener type used in cold-formed steel construction, although the standard does not preclude the use of other fastener types. Installation guidelines for self-drilling screws are provided by AISI S200 (AISI, 2007b).

To maintain acceptable durability of a welded connection, AISI S200 requires that the weld area be treated with a corrosion resistant coating.

B2.2 Stud-to-Track Connection for C-Section Studs

When the *track* thickness is equal to or greater than the *stud* thickness, an increase in web crippling strength can be realized. This increased strength is attributed to the favorable synergistic effect of the *stud*-to-*track* assembly. The provisions are based on research conducted at the University of Waterloo (Fox and Schuster, 2000) and the University of Missouri-Rolla (Bolte, 2003).

Two proposed design equations were considered for adoption by Section B2.2 of the standard for evaluating the design strength of the *stud*-to-*track* connection for *curtain wall* applications. The proposed UMR equation (Bolte, 2003) reflected the specific contribution of the screw as follows:

$$P_{nst} = P_n + \Delta\, P_{not}$$

Where:

Δ = 0.756

P_n = web crippling capacity in accordance with Section C3.4.1 of AISI S100 [CSA S136] for end-one-flange loading

P_{nst} = nominal strength for the *stud*-to-*track* connection when subjected to transverse loads

P_{not} = screw pull-out capacity in accordance with Section E4.4.1 of AISI S100 [CSA S136]

The proposed University of Waterloo equation was based on a formulation proposed by Fox and Schuster (2000). The design formulation for the *stud*-to-*track* connection was based on a pure web crippling behavior consistent with Section C3.4 of AISI S100 [CSA S136]. To reflect the positive contribution of the screw attachment, Fox and Schuster (2000) proposed modified web crippling coefficients as follows:

$$P_n = Ct^2F_y\sin\theta\left(1 - C_R\sqrt{\frac{R}{t}}\right)\left(1 + C_N\sqrt{\frac{N}{t}}\right)\left(1 - C_h\sqrt{\frac{h}{t}}\right)$$

Where:

P_n = nominal crippling strength per Section C3.4.1 of AISI S100 [CSA S136] with the following coefficients

C = Web crippling coefficient = 5.6

C_R = Inside bend radius coefficient = 0.01
C_N = Bearing length coefficient = 0.30
C_h = Web slenderness coefficient = 0.14
R = *stud* inside bend radius
N = *stud* bearing length
h = depth of flat portion of *stud web* measured along plane of *web*
t = *stud* design thickness
θ = angle between plane of *web* and plane of bearing surface, $45° < \theta \leq 90°$

Based on the additional tests, performed at UMR and the University of Waterloo, the following coefficients are recommended:

C = Web crippling coefficient = 3.7
C_R = Web slenderness coefficient = 0.19
C_N = Bearing length coefficient = 0.74
C_h = Inside bend radius coefficient = 0.019

Although there are pros and cons to each design equation, statistically they yield similar results as shown in the following:

Table B2.2-1
Comparison of Proposed Design Equations

Parameter	Waterloo Model	UMR Model
Mean	1.001	1.000
Coeff. of Variation	0.101	0.078
Ω	1.74	1.71
ϕ (LRFD)	0.88	0.90

The factor of safety and resistance factor are based on assuming a member failure mode, not a connection failure mode.

Although both the UMR and University of Waterloo design methods will yield similar design strengths, for simplicity of design it was decided to adopt the University of Waterloo design method for the standard. For simplicity, since $\theta = 90°$ and; therefore, $\sin\theta = 1$, the $\sin\theta$ term was eliminated from Equation B2.2-1 in the standard.

When the *track* thickness is less than the *stud* thickness, the proposed provisions are based on the study by Fox and Schuster (2000).

The 0.5 applied to P_{nst} for locations adjacent to wall openings is based on a study by Daudet (2001).

B2.3 Deflection Track Connection for C-Section Studs

The provisions contained in the standard apply to a *C-section* wall *stud* installed in a single *deflection track* application and are based on research at the Milwaukee School of Engineering (Gerloff, 2004). Based on this research, the load capacity [resistance] can be established by the equations in the standard. The key parameters, as given by the equations, are defined by Figure B2.3-1.

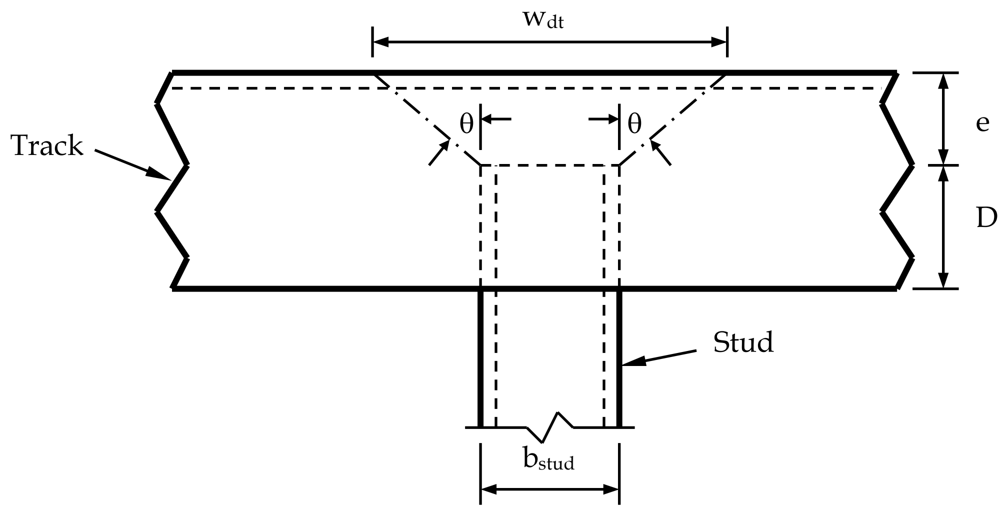

Figure B2.3-1 Deflection Track Connection

Because the *deflection track* detail does not provide torsional restraint for the wall *stud*, it is recommended that a line of bridging be installed near the end of the member.

For Figure B2.3-1, dimension "e" is selected for the sum of construction tolerances and the deflection of the floor above relative to the floor or foundation below. Dimension "D" is selected so that adequate *stud* to *track* engagement and *web* crippling bearing length remains when the floor below deflects relative to the floor above.

The background research for this provision did not include *studs* at or near terminations in the top *track*. For this case, the strength and serviceability of the connection may be reduced.

B3 Bracing

The requirement in the standard that each brace be designed for 2% of the design compression load [force] in the member is based on a long-standing industry practice.

Bracing requires periodic anchorage. Bracing forces are accumulative between anchorage points.

B3.1 Intermediate Brace Design

Brace forces are additive, thus the standard requires consideration of combined brace forces when designing braces for members that experience combined loading. Design guidance is provided in AISI D110-08, *Cold-Formed Steel Framing Design Guide* (AISI, 2007).

B4 Serviceability

The standard does not stipulate serviceability limit states. However, the *International Building Code* (ICC, 2012) sets forth deflection limits in Sections 1604.3 and 1405.9.1.1, and the *NFPA 5000* (NFPA, 2012) sets forth similar provisions in Section 37.1.2.8 for use in the United States and Mexico. Likewise, the *User's Guide - NBC 2005 Structural Commentaries (Part 4, of Division B)* (NRC, 2005) sets forth deflection limits for use in Canada.

C. INSTALLATION

The wall *stud* should be nested or seated into the *track* to provide for adequate transfer of the forces. The maximum gap tolerance specified by the standard for *curtain walls* is based on acceptable industry practice.

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