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AISI Standard for Cold-Formed Steel Framing – Wall Stud Design, 2004 Edition

American Iron and Steel Institute

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American
Iron and Steel
Institute

AISI STANDARD

Standard for
Cold-Formed Steel Framing –
Wall Stud Design,
2004 Edition

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 may eventually 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 there from.

PREFACE

The American Iron and Steel Institute (AISI) Committee on Framing Standards (COFS) has developed this *Standard for Cold-Formed Steel Framing – Wall Stud Design* [*Wall Stud Standard*] to provide technical information and specifications for designing wall *studs* made from cold-formed steel.

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 and encouragement of the Steel Framing Alliance.

All terms in this *Wall Stud Standard* written in italics are defined in the AISI *Standard for Cold-Formed Steel Framing – General Provisions*. Any listed definitions identified with [*reference*/year] are defined in the referenced document and listed to ease use of this *Wall Stud Standard*.

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STANDARD FOR COLD-FORMED STEEL FRAMING –
WALL STUD DESIGN

A. GENERAL

A1 Scope

The design and installation of cold-formed steel *studs* for both *structural* and *non-structural walls* in buildings shall be in accordance with the *North American Specification for the Design of Cold-Formed Steel Structural Members* [*Specification*] and the *Standard for Cold-Formed Steel Framing – General Provisions* [*General Provisions*] except as modified by the provisions of this *Wall Stud Standard*. This *Wall Stud Standard* does not intend to preclude the use of other materials, assemblies, structures, or designs not meeting the criteria herein. However, it must be demonstrated that equivalent performance will be achieved for the intended use as specified in this *Wall Stud Standard*. Where there is a conflict between this *Wall Stud Standard* and other reference documents the requirements contained herein shall govern. This *Wall Stud Standard* shall include Sections A through D inclusive.

A2 Definitions

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

Curtain Wall. A wall that transfers lateral (transverse) loads and is limited to a superimposed vertical load, exclusive of sheathing materials, of not more than 100 lb/ft (1460 N/m), or a superimposed vertical load of not more than 200 lbs (890 N).

Nominal Load. Magnitude of the load specified by the *applicable building code*. [*AISC/AISI Terminology*/2004]

Structural Wall. A wall that supports superimposed vertical loads and which may transfer lateral loads.

Non-Structural Wall. A steel framed wall system which is limited to a lateral (transverse) load of not more than 5 lb/ft² (240 Pa), a superimposed vertical load, exclusive of sheathing materials, of not more than 100 lb/ft (1460 N/m), or a superimposed vertical load of not more than 200 lbs (890 N).

A3 Referenced Documents

The following documents are referenced in this *Wall Stud Standard***:**

1. AISI, *North American Specification for the Design of Cold-Formed Steel Structural Members*, 2001 Edition with 2004 Supplement, American Iron and Steel Institute, Washington, DC.

2. AISI, *Standard for Cold-Formed Steel Framing–General Provisions*, 2004 Edition, American Iron and Steel Institute, Washington, DC.

3. ASCE 7-02, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, VA.

B. LOADING

B1 Load Combinations

The loads and load combinations to be used in the design of cold-formed steel wall *studs* shall be as established by the *applicable building code*, or by ASCE 7 in the absence of an *applicable building code*, except as modified in this section.

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% of Components and Cladding (C&C) wind loads with no axial loads.

C. DESIGN

C1 Materials

Sheet steel materials utilized in the steel wall *stud* construction shall comply with the requirements for *structural members* defined in the *General Provisions* or the *Specification*.

C2 Corrosion Protection

Wall *studs*, *track*, and fasteners shall have corrosion protection as required by the *General Provisions*.

C3 Member Design

Wall *studs* shall be designed either on the basis of an all steel design or on the basis of sheathing braced design. Both solid *webs* or *webs* with holes that satisfy the limits of the *Specification* shall be permitted.

(a) All Steel Design. Wall *stud* assemblies using an all steel design shall be designed neglecting the structural contribution of the attached sheathings.

(b) Sheathing Braced Design. The engineering drawings must identify the sheathing as a structural element, and alterations to the sheathing must be reviewed and approved by an engineer. When sheathing braced design is used, the wall *stud* shall be evaluated without the sheathing *bracing* for the following load combination:

$$1.2D + (0.5L \text{ or } 0.2S) + 0.2W \qquad\qquad (Eq. \text{ C3-1})$$

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 permitted to be designed based on the assumption that the weaker of the two sheathings is attached to both sides.

C3.1 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 the *Specification*.

C3.2 Wall Studs in Compression

For all steel design, Section C4 and D4(a) of the *Specification* define the design axial strength. The effective length, KL, shall be permitted to be determined by rational analysis and/or testing. In the absence of such analysis or tests, K_x, K_y and K_t shall be taken as unity. The unbraced length 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.

For sheathing braced design, the design axial strength shall be determined in accordance with the provisions of this section.

The design axial strength shall be calculated using Section C4 of the *Specification*. The unbraced length with respect to the major axis, L_x, shall be taken equal to the distance

between the member's ends. 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, when identical gypsum sheathing is attached to both sides of the wall *stud* with screws spaced at a maximum of 12 inches (300 mm) on center, the maximum nominal axial load in the wall *stud* shall be limited to the values given in Table C3.2-1.

Table C3.2-1
Maximum Axial Load Limited by Gypsum Sheathing-to-Wall Stud Connection Capacity

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

C3.3 Wall Studs in Bending

For all steel design, Section C3.1.2.1 of the *Specification* defines the design flexural strength.

For sheathing braced design, and neglecting any rotational restraint provided by the sheathing, Section C3.1.1 of the *Specification* defines the design flexural strength.

C3.4 Wall Studs in Shear

For either all steel design or sheathing braced design, the design shear strength is defined by Section C3.2 of the *Specification*.

C3.5 Wall Studs in Combined Axial Load and Bending

For either all steel design or sheathing braced design, the required axial strength and flexural strength shall satisfy the interaction equations of Section C5 of the *Specification*.

C3.6 Web Crippling

For either all-steel design or sheathing braced design, the web crippling strength alone shall be determined by using Section C3.4 of the *Specification*. P_n shall be permitted to be modified in accordance with Section C4.2 of this *Wall Stud Standard* for the increased strength due to the *track*.

C3.7 Built-up Sections

For either all steel design or sheathing braced design, the design strength of built-up sections is defined by Section C4.5 of the *Specification*. When the connection requirements of the *Specification* are not met, the design strength of built-up sections shall be equal to the sum of the design strengths of the individual members of the built-up cross section.

C4 Connection Design

C4.1 Fastening Methods

Screw, bolt, and weld connections shall be designed in accordance with the *Specification* and *General Provisions*. For connections using other fastener types, design values shall be determined by testing in accordance with Section F1 of the *Specification*.

C4.2 Stud-to-Track Connection for C-Section Studs

The *stud*-to-*track* connection shall provide adequate bearing length in order to satisfy the requirements for web crippling design strength of the *stud*, in accordance with sections C3.6 and D1 of this *Wall Stud Standard*, or as defined in this section.

(a) For *curtain wall studs* that are not adjacent to wall openings and when both *stud flanges* are connected to the *track flanges* and the *track* thickness is greater than or equal to the *stud* thickness:

$$P_{nst} = Ct^2 F_y \left(1 - C_R \sqrt{\frac{R}{t}}\right) \left(1 + C_N \sqrt{\frac{N}{t}}\right) \left(1 - C_h \sqrt{\frac{h}{t}}\right) \qquad (Eq.\ C4.2\text{-}1)$$

Where:

P_{nst}	=	nominal crippling strength
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
ϕ	=	0.90

The above equation is 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)

<u>Track 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)
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 when both *stud flanges* are connected to the *track flanges* and the *track* thickness is less than the *stud* thickness, the capacity is the lesser of Equations C4.2-1 or C4.2-2:

$P_{nst} = 0.6\ t_t\ w_{st}\ F_{ut}$ $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ (*Eq.* C4.2-2)

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
ϕ	=	0.90

(c) For *curtain wall studs* that are adjacent to wall openings and when both *stud flanges* are connected to the *track flanges* and the track terminates at the opening, the nominal capacity shall be taken as $0.5\,P_{nst}$ using Ω and ϕ, as determined above.

(d) For *curtain wall studs* that do not have both *stud flanges* connected to the *track flanges*, P_{nst} shall equal P_n, along with Ω and ϕ, as determined by Section C3.4.1 of the *Specification*.

C4.3 Deflection Track Connection for C-Section Studs

The *nominal strength* of a single *deflection track* shall be determined as follows:

$$P_{ndt} = \frac{w_{dt}\,t^2 F_y}{4e} \qquad\qquad (Eq.\ C4.3\text{-}1)$$

$$w_{dt} = 0.11(\alpha^2)(e^{0.5}/t^{1.5}) + 5.5\alpha \le S$$

Where:

P_{ndt}	=	nominal strength of *deflection track* when subjected to transverse loads
w_{dt}	=	effective track length
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
ϕ	=	0.55

The above equation is 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)

C5 Bracing

C5.1 Intermediate Brace Design

For bending members, each intermediate brace shall be designed in accordance with Section D3.2.2 of the *Specification*.

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

C6 Serviceability

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

D. INSTALLATION

Wall *studs* shall be installed in accordance with the *General Provisions* and the following requirements.

D1 Stud-to-Track Connection

The *stud flange* shall engage the *track flange* sufficiently to meet the requirements of Section C4.2 of this *Wall Stud 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 C3.4.4 of the *General Provisions*.

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.

American Iron and Steel Institute

AISI STANDARD

Commentary on the Standard for Cold-Formed Steel Framing – Wall Stud Design, 2004 Edition

Endorsed by:

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PREFACE

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

In the *Commentary*, sections, equations, figures, and tables are identified by the same notation as used in the *Wall Stud Standard*.

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

A. GENERAL

A1 Scope

This *Wall Stud Standard* applies to the design and installation of cold-formed steel *studs* for both *structural* and *non-structural walls* in buildings.

A2 Definitions

Codes and standards by their nature are technical, and as such specific words and phrases can change the intent of the provisions if not properly defined. As a result, it is necessary to establish common terminology by clearly stating the meaning of specific terms for the purpose of this *Wall Stud Standard*.

This *Wall Stud Standard* does not report specific dimensions for *studs* or *tracks* due to the lack of an industry product standard. For example, *deflection track* is defined as having extended *flanges*. Usually *deflection track flanges* range from 1 ½ inch (38 mm) to 3 inch (76 mm) in length.

B. LOADING

B1 Load Combinations

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 B of ASCE 7-98 (ASCE, 1998) 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 exclusively 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.

C. DESIGN

C2   Corrosion Protection

As prescribed by the *General Provisions* (AISI, 2004b), the minimum coating approved for use for either *structural* or *non-structural wall studs* must comply with ASTM A1003/1003M.

C3   Member Design

The *Wall Stud 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 *Wall Stud 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 load combination is taken from ASCE 7-02 (ASCE, 2002) for special event loading conditions:

$$1.2D + (0.5L \text{ or } 0.2S) + 0.2W \tag{Eq. C3-1}$$

Although the design approach for sheathing braced design is based upon engineering principals, the *Wall Stud 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.

C3.2 Wall Studs in Compression

Prior to 2004, the *Specification* (AISI, 2004a) contained requirements for sheathing braced design in its Section D4(b). In 2004, these provisions were removed. The *Specification* now permits sheathing braced design in accordance with an appropriate theory, tests, or rational engineering analysis.

Sheathing braced design in the *Wall Stud 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:

$$F_{br} = K (\Delta + \Delta_o) = 0.02 P \tag{Eq. C3-2}$$

Where:

$\Delta \qquad = \Delta_o = L/384$

$L \qquad$ = total stud height

$$K = 4P/L$$

The limit of L/384 is based on the maximum bow of 1/32 inch/foot as prescribed by Table A5.1 of the *General Provisions*. The tests indicated a failure of the sheathing, not the screw to stud attachment. Thus, the *Wall Stud 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 allowable load for the gypsum wallboard. The ultimate loads are based on the averaging of test data provided in Miller (1989) and Lee (1995).

Table C3.2-1
Maximum Axial Load Limited by Gypsum Sheathing-to-Wall Stud Connection Capacity

Sheathing	Screw Size	Ultimate Load (per screw)	Allowable Load (per screw)
1/2 inch	No. 6	0.117 kips (0.516 kN)	0.058 kips (0.258 kN)
1/2 inch	No. 8	0.134 kips (0.596 kN)	0.067 kips (0.298 kN)
5/8 inch	No. 6	0.136 kips (0.605 kN)	0.068 kips (0.302 kN)
5/8 inch	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 $D \le 0.17''$

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

$Z = 0.164 \times 0.5 \times 1900 / 2.2 = 70.82$ 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:

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

$\Omega = 3.0$

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 *Wall Stud 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.

C4   Connection Design

C4.1   Fastening Methods

Self-drilling screws are the primary fastener type used in cold-formed steel construction, although the *Wall Stud Standard* does not preclude the use of other fastener types. Installation guidelines for self-drilling screws are provided by the *General Provisions*.

To maintain acceptable durability of a welded connection, the *General Provisions* requires that the weld area must be treated with a corrosion resistant coating.

C4.2   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 C4.2 of the *Wall Stud 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 the *Specification* 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 the *Specification*

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 the *Specification*. To reflect the positive contribution of the screw attachment, Fox and Schuster (2000) proposed modified web crippling coefficients as follows:

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

Where:

P_n = nominal crippling strength per Section C3.4.1 of the *Specification* 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 C4.2-1
Comparison of Proposed Design Equations

	Waterloo Model	UM-R Model
Mean	1.001	1.000
Coeff. of Variation	0.101	0.078
Ω	1.74	1.71
ϕ	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 *Wall Stud Standard*. For simplicity, since $\theta = 90°$ and; therefore, $\sin\theta = 1$, the $\sin\theta$ term was eliminated from Equation C4.2-1 in the *Wall Stud 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).

C4.3 Deflection Track Connection for C-Section Studs

The provisions contained in the *Wall Stud 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 can be established by the equations in the *Wall Stud Standard*. The key parameters, as given by the equations, are defined by Figure C4.3-1.
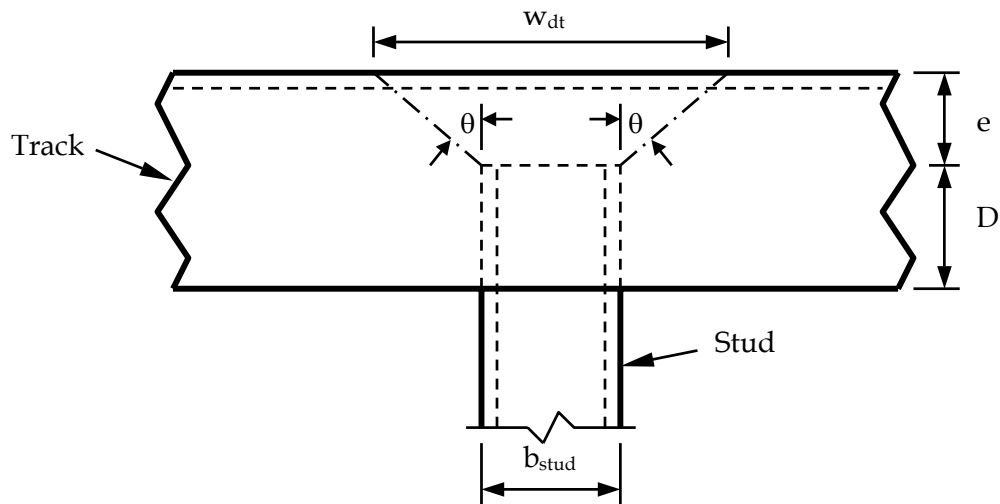

Figure C4.3-1 Deflection Track Connection

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 C4.3-1, 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.

When the stud is at or near a termination in the top track, the strength and serviceability of the connection may be reduced. Industry practice is that the stud be located a distance away from the end of the track equal to half the effective track length, w_{dt}.

C5 Bracing

The *Wall Stud Standard* requirement that each brace be designed for 2% of the design compression load in the member is based on a long-standing industry practice.

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

C5.1 Intermediate Brace Design

Brace forces are additive, thus the *Wall Stud Standard* requires consideration of combined brace forces that when designing braces for members that experience combined loading. Design guidance is provided in AISI Design Guide CF02-1 (AISI, 2002).

C6 Serviceability

The *Wall Stud Standard* does not stipulate serviceability limit states. However, the International Building Code (ICC, 2003) does set forth deflection limits in Sections 1604.3 and 1405.9.1.1, and the NFPA (NFPA, 2003) sets forth similar provisions in Section 37.1.2.8.

D. 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 *Wall Stud Standard* for *curtain walls* is based on acceptable industry practice.

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