



AISI S310-23



**American
Iron and Steel
Institute**

AISI STANDARD

North American Standard for the Design of Profiled Steel Diaphragm Panels

2023 Edition



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The material contained herein has been developed by the American Iron and Steel Institute (AISI) Committee on Specifications. The Committee has made a diligent effort to present accurate, reliable, and useful information on cold-formed steel *diaphragm* design. 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 *diaphragms* and the continuing development of new technology, this material may eventually become dated. It is anticipated that future editions of this *Standard* will update this material as new information becomes available, but this cannot be guaranteed.

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PREFACE

The American Iron and Steel Institute Committee on Specifications has developed AISI S310-23, the 2023 Edition of the *North American Standard for the Design of Profiled Steel Diaphragm Panels*, to provide design provisions for *diaphragms* consisting of profiled steel *decks* or *panels* which include fluted profiles and *cellular deck* profiles. This *Standard* is intended for adoption and use in the United States, Canada, and Mexico.

User Notes are non-mandatory portions of this *Standard*.

The major changes of this edition include:

- The standard sections have been reorganized to improve ease of use.
- The specific section for standing seam panels has been removed, but the design is covered under test-based design.
- The sections for double skin panels and the appendix for combined shear and axial loading case have been moved to design examples (not included).
- Connection strength of panels to steel supports is in accordance with AISI S100.
- Wood screw connection strength is in accordance with the ANSI/NDS, *National Design Standard for Wood Construction*.
- Test-based design follows the provisions of AISI S100.
- Flexibility of connections and connection strength not in included AISI S100 have been moved to Appendix 1.

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.

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December 2023

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SYMBOLS AND DEFINITIONS

A	= Number of exterior support <i>connections</i> per flute located at the <i>sidelap</i> at an <i>interior panel</i> or <i>edge panel</i> end	D1.1
A_a	= Material shear deformation component for <i>cellular panel</i> or <i>perforated cellular panel</i>	D3.2, D4.2, F2.2
A_e	= Ratio of bottom perforated width to the bottom width	D2.1
A_f	= Ratio of top perforated width to the top width	D2.1
A_i	= Ratio of perforated width to the full element width	D2.1
A_v	= Cross-sectional area per unit width, b , of reinforcement oriented parallel to the direction of shear, in. ² (mm ²)	E1.1
A_w	= Ratio of web perforated width to the <i>web</i> width	D2.1
b	= Unit width of <i>diaphragm</i> with structural concrete fill, 12 in. for U. S. customary units and 1000 mm for SI units	E1.1
C	= Slip constant considering slippage at <i>sidelap connections</i> and distortion at support <i>connections</i>	D1.2, D3.2, D4.2, F1.2, F2.2
C_f	= Calibration coefficient	G2.2
c_p	= Hole center-to-center spacing	D2.1
d	= <i>Panel</i> corrugation pitch, in. (mm)	D1.1, D1.2, E1.1, E1.2, F1.2
d	= Top profiled <i>panel</i> corrugation pitch, in. (mm)	D3.2
d'	= Equivalent width of <i>cellular panel</i> perforated bottom plate adjusted for perforations and measured between longitudinal rows of fasteners connecting the top <i>profiled panel</i> to the bottom plate, in. (mm)	D4.2
d_c	= Structural concrete thickness above top of profiled <i>panel</i> , in. (mm)	E1.2, F1.1, F1.2
D_d	= Depth of <i>panel</i> , in. (mm)	D1.1, E1.2
D_n	= Unitless warping factor considering distortion at <i>panel</i> ends determined using the parameters as shown in Figure D1.1-1	D1.2
d_o	= Hole diameter in washer, in. (mm)	1.2.3.1
d_p	= Perforation hole diameter	D2.1
e	= One-half the bottom flat width of <i>panel</i> measured between points of intercept as illustrated in Figure D1.1-1, in. (mm)	D1.1

E	= Modulus of elasticity of steel, ksi (MPa)	D1.2, E1.1, E1.2, F1.2, F2.2
e	= Distance from the top <i>profiled panel</i> longitudinal fastener to the web, in. (mm)	D3.2
E_c	= Modulus of elasticity of concrete in accordance with ACI 318, ksi (MPa)	E1.1, E1.2
E_p	= Width of perforation band in the bottom flat of width, $2e$, in. (mm)	D2.2
f	= Top flat width of panel measured between points of intercept illustrated in Figure D1.1-1, in. (mm)	D1.1, D2.1, D3.2
f'_c	= Specified concrete structural compressive strength, psi (MPa)	E1.1, E1.2, F1.1, F1.2
f'_c	= Material shear deformation component for <i>perforated cellular panel</i> determined in accordance with Section D4.2	F2.2
F_m	= Mean value of fabrication factor, F , determined by statistical analysis or where applicable, as limited by AISI Table K2.1.1-1 for type of component involved	G2.2
F_p	= Width of perforation band in the top flat of width, f , in. (mm)	D2.2
F_{xx}	= Tensile strength of electrode classification, ksi (MPa)	1.2.3.1
F_y	= Design <i>yield stress</i> as determined in accordance with AISI S100 Section A3.3.1	D1.1
F_{ys}	= Specified minimum <i>yield stress</i> of reinforcement, ksi (GPa)	E1.1
G'	= <i>Diaphragm shear stiffness</i> , kip/in. (kN/m)	F1.2, B3.2.4, B3.3, B3.7, D1.2, D2.2, D3.2, E1.2, E2.2, F1.2, G2.2
h	= Flat dimension of web measured in <i>plane of web</i>	D1.1, D2.1
i	= Index of perforated elements in a profile	D2.1
I_{xg}	= Moment of inertia of fully effective <i>panel</i> per unit width, in. ⁴ /ft (mm ⁴ /mm)	D1.1
K	= <i>Stiffness</i> factor relating support and <i>sidelap connection</i> flexibilities	D1.2
k	= Ratio of the perforated element stiffness relative to that of a solid element	D2.1, D2.2
K_3	= <i>Stiffness</i> contribution of the insulating concrete fill	F1.2, F2.2

k_b	= Ratio of perforated element <i>stiffness</i> relative to that of a solid element in the perforated bottom plate of <i>cellular panel</i> of the same thickness, t_b , and determined in accordance with Eqs. D2.1-5 and D2.1-6	D4.2
k_c	= Factor for structural concrete strength	E1.1
L	= Total panel length	D1.1, D1.2
L_v	= Span of <i>panel</i> between supports with fasteners, ft (m)	D1.1
L_w	= Length of top arc seam <i>sidelap</i> weld, in. (mm). See AISI S100 Figure J2.4.1-1 for details.	1.2.4.1
M_m	= Mean value of material factor, M , determined by statistical analysis or, where applicable, as limited by AISI S100 Table K2.1.1-1 for type of component involved	G2.2
N	= Number of support fasteners per unit width at an interior or edge panel's end	D1.1, D3.1
N_c	= Average number of support fasteners per unit width	E1.1
n_d	= Number of support <i>connections</i> at the flute bottom relative to the tributary width, w_t , along the ends of interior or <i>edge panels</i> and into exterior supports	D1.1
n_e	= Number of edge support <i>connections</i> between transverse supports and along an <i>edge panel</i> length, L	D1.1
N_{ext}	= Bearing length at exterior support (3/4 in. (19 mm) minimum)	D1.1
n_p	= Number of interior supports along a total <i>panel</i> length, L	D1.1, D1.2
n_s	= Number of <i>sidelap connections</i> along a total <i>panel</i> length, L , and not into supports	D1.1, D1.2
n_{sc}	= Modular ratio of steel <i>profiled panel</i> to concrete	E1.1
P_n	= <i>Nominal shear strength [resistance]</i> of arc spot weld with washer, kip (kN)	1.2.3.1
P_{nf}	= <i>Nominal shear strength [resistance]</i> of a support <i>connection</i> per fastener determined in accordance with Appendix 1	D1.1, D3.1
P_{nf}	= <i>Nominal shear strength [resistance]</i> of a support <i>connection</i> per fastener determined in accordance with AISC 360 for welded steel headed stud anchors or Appendix 1 as applicable	E1.1

P_{nf}	Nominal shear strength [resistance] of a support connection per fastener in the absence of a tensile load	1.4.1
P_{nfs}	Nominal shear strength [resistance] of an edge support connection installed parallel with an edge panel span and between transverse supports	D1.1
P_{nft}	Nominal shear strength [resistance] of a support connection per fastener in the presence of a tensile load	1.4.1
P_{not}	Nominal tension strength [resistance] of a support connection per power-actuated fastener controlled by pull-out	1.4.1
P_{nov}	Nominal tension strength [resistance] of a support connection per power-actuated fastener controlled by pull-over	1.4.1
P_{ns}	Nominal shear strength [resistance] of a sidelap connection per fastener determined in accordance with Appendix 1	D1.1
p_o	Ratio of the area of perforations to the total area in the perforated band	D2.1
q_s	Perforated web adjustment factor	D1.1
R	Inside bend radius	D1.1
s	Developed flute width per pitch, in. (mm)	D1.1, D1.2, E1.1, E1.2, F1.2
s	Developed flute width of top profiled panel in a cellular panel in accordance with Eq. D1.1-15	D3.2
s'	Developed flute width of top profiled panel per width, w_d , in a cellular panel in accordance with Eq. D2.2-1	D4.2
S_{ni}	Nominal shear strength [resistance] per unit length of diaphragm or wall diaphragm controlled by connections at interior panels or edge panels	D1.1
S_{nc}	Nominal shear strength [resistance] per unit length of diaphragm or wall diaphragm controlled by support connections at the corners of interior panels or edge panels	D1.1
S_{ne}	Nominal shear strength [resistance] per unit length of diaphragm or wall diaphragm controlled by connections along the edge parallel to the panel span in an edge panel and located at a diaphragm reaction line	D1.1
S_{np}	Nominal shear strength [resistance] per unit length of diaphragm or wall diaphragm controlled by connections	D1.1

	along the ends of <i>interior panels</i> or <i>edge panels</i> and into exterior supports	
S_{no}	= Nominal shear strength [resistance] per unit length of diaphragm or wall diaphragm controlled by panel out-of-plane buckling, kip/ft (kN/m)	D1.1
S_{nl}	= Nominal shear strength [resistance] per unit length of diaphragm or wall diaphragm controlled by panel local web buckling over exterior support	D1.1
S	= Connection shear flexibility, in./kip (mm/kN)	1.2.1, 1.2.2, 1.2.4.1, 1.3.1, 1.5.2, 1.6.2
S_f	= Structural support connection shear flexibility determined in accordance with Appendix 1, in./kip (mm/kN)	D1.2
S_s	= Sidelap connection shear flexibility determined in accordance with Appendix 1, in./kip (mm/kN)	D1.2
t	= Base metal thickness of the panel, in. (mm)	D1.1, D1.2, F1.2
t	= Base steel thickness of top profiled panel in cellular panel, in. (mm)	D3.2, E1.1, E1.2, F1.2
t	= Total combined base steel thickness of panel involved in shear transfer above the shear transfer plane, in. (mm)	1.2.1, 1.2.2, 1.2.3.1, 1.5.2, 1.6.2
t	= Total combined base steel thickness (exclusive of coatings) of sheets beneath the washer and above the shear transfer plane, in. (mm)	1.2.3.1
t	= Base steel thickness of thinner connected sheet, in. (mm)	1.2.4.1
T	= Required allowable tensile strength of a support connection per fastener determined for ASD loads and load combinations in accordance with Section A3	1.4.1
	= Required tensile strength [tensile force due to factored loads] of a support connection per fastener determined for LRFD or LSD loads and load combinations in accordance with Section A3	1.4.1
t_1	= Thickness of member in contact with screw head or washer, in. (mm)	1.3.1
t_2	= Thickness of member not in contact with screw head or washer, in. (mm)	1.3.1

t_a	= Average thickness of structural concrete, calculated as the cross-sectional area of the structural concrete over one <i>profiled panel</i> divided by the width of the <i>profiled panel</i> , in. (mm)	E1.1
t_b	= Base steel <i>thickness</i> of bottom plate in <i>cellular panel</i> , in. (mm)	D3.2
t_e	= Equivalent transformed concrete thickness, in. (mm)	E1.1
U_1	= Number of corrugations having fasteners in every valley across the <i>panel</i> width, w	D1.2
U_2	= Number of corrugations having fasteners in every second valley across the <i>panel</i> width, w	D1.2
U_3	= Number of corrugations having fasteners in every third valley across the <i>panel</i> width, w	D1.2
U_4	= Number of corrugations having fasteners in every fourth valley across the <i>panel</i> width, w	D1.2
V_F	= Coefficient of variation of fabrication factor listed in AISI S100 Table K2.1.1-1 for type of component involved	G2.2
V_M	= Coefficient of variation of material factor listed in AISI S100 Table K2.1.1-1 for type of component involved	G2.2
V_Q	= Coefficient of variation of load effect	G2.2
w	= <i>Panel</i> cover width	D1.1, D1.2
w	= Web flat width of <i>panel</i> measured between points of intercept illustrated in Figure D1.1-1, in. (mm)	D1.1
w	= <i>Web</i> flat width of top <i>profiled panel</i> measured between points of intercept illustrated in Figure D1.1-1, in. (mm)	D3.2
w_d	= Distance measured across the width and between longitudinal rows of fasteners connecting the top <i>profiled panel</i> to the bottom plate, in. (mm)	D3.2, D4.2
w_{dp}	= Total width of perforation bands in bottom plate width, w_d , in. (mm)	D4.2
w_e	= <i>Panel</i> cover width at the <i>edge panel</i>	D1.1
W_p	= Width of perforation band in <i>web</i> flat of width, w	D2.1, D2.2

w_t	Tributary width to any given bottom flute with support connection(s) along the end perpendicular to the <i>panel</i> span and located at exterior support	D1.1
x_e	Distance from <i>panel</i> centerline to an exterior support connection in a <i>panel</i>	D1.1, D1.2
x_{ee}	Distance from <i>panel</i> centerline to an exterior support connection in an <i>edge panel</i>	D1.1
x_p	Distance from <i>panel</i> centerline to an interior support connection in a <i>panel</i>	D1.1, D1.2
x_{pe}	Distance from <i>panel</i> centerline to an interior support connection in an <i>edge panel</i>	D1.1
Z'	LRFD-adjusted lateral design value, Z , in accordance with NDS	1.6.1
α	Conversion factor for units	D1.1, 1.2.1, 1.2.2, 1.2.4.1, 1.3.1, 1.5.2, 1.6.2
α_3	Measure of exterior support fastener group distribution across a <i>panel</i> width	D1.2
α_4	Measure of interior support fastener group distribution across a <i>panel</i> width, w , at an <i>interior panel</i>	D1.2
α_5	Conversion factor for units	1.2.4.1
β	Factor defining <i>connection</i> contribution and interaction to diaphragm shear strength per unit length	D1.1
β_o	Target reliability index	G2.2
δ_{bi}	Lateral displacement indicator at bottom of corrugation for valley fastener cases, $i = 1$ to 4, in. ^{2.5} (mm ^{2.5})	D1.2
δ_{ij}	Deflection indicator of profile racking per unit load per unit length required for D, in. ³ (mm ³)	D1.2
δ_{ti}	Lateral displacement indicator at top of corrugation for valley fastener cases, $i = 1$ to 4, in. ^{2.5} (mm ^{2.5})	D1.2
ϕ	Lateral <i>resistance factor</i> in accordance with NDS	1.6.1
ϕ_{tot}	<i>Resistance factor</i> for a <i>power-actuated fastener</i> controlled by pull-out and determined by test using AISI S100 Chapter K	1.4.1

ϕ_{tov}	= Resistance factor for a power-actuated fastener controlled by pull-over	1.4.1
γ_c	= Support factor for warping determined in accordance with Table D1.2-1	D1.2
γ_i	= Final displacement indicator at top of corrugation for valley fastener cases, $i = 1$ to 4, in. ^{2.5} (mm ^{2.5})	D1.2
λ	= Connection strength reduction factor at corner fastener, unitless	D1.1
μ	= Poisson's ratio for steel	D1.2, F1.2
Ω_{tot}	= Safety factor for a power-actuated fastener controlled by pull-out and determined by test using AISI S100 Chapter K	1.4.1
Ω_{tov}	= Safety factor for a power-actuated fastener controlled by pull-over	1.4.1
θ	= Angle between plane of web and plane of bearing surface, $45^\circ \leq \theta \leq 90^\circ$	D1.1
λ_{LW}	= Factor for lightweight concrete	E1.1

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NORTH AMERICAN STANDARD FOR THE DESIGN OF PROFILED STEEL DIAPHRAGM PANELS

A. GENERAL PROVISIONS

This chapter addresses the scope and applicability of the *Standard*, lists the definitions of the terminology used, summarizes referenced specifications, codes, and standards, and provides requirements for materials.

The chapter is organized as follows:

A1 Scope, Applicability, and Definitions

A2 Reference Specifications, Codes, and Standards

A3 Materials

A1 Scope, Applicability, and Definitions

A1.1 Scope

This *Standard* applies to the design of in-plane shear strength and *shear stiffness* for *panels* and associated fasteners commonly used as the stressed skin of

- (a) *Diaphragms*, and
- (b) *Wall diaphragms* (shear walls).

This *Standard* does not address determination of *available strength* [*factored resistance*] for the other components in a *diaphragm* or *wall diaphragm* system.

This *Standard* shall apply to *panels* that are installed:

- (c) With or without insulation between the *panel* and the support,
- (d) With or without concrete fill over the *panel*,
- (e) With or without perforations in the *panel*, and
- (f) With structural supports made of steel, wood, or concrete.

This *Standard* does not preclude the use of other materials, assemblies, structures or designs if the other materials, assemblies, structures or designs demonstrate equivalent performance for the intended use of those specified in this *Standard*. Where there is a conflict between this *Standard* and other reference documents, the requirements contained within this *Standard* govern.

A1.2 Applicability

This *Standard* includes Symbols, Chapters A through G, and Appendix 1.

This *Standard* includes design provisions for *Allowable Strength Design (ASD)*, *Load and Resistance Factor Design (LRFD)*, and *Limit States Design (LSD)*. These design methods shall apply as follows:

- *ASD* and *LRFD* – the United States and Mexico, and
- *LSD* – Canada.

In this *Standard*, bracketed terms are equivalent terms that apply particularly to *LSD*.

The in-plane *nominal shear strength* [*resistance*] and *shear stiffness* of *diaphragm* or *wall diaphragm* profiled panels or *cellular panels* shall be determined in accordance with Chapters C through G and Appendix 1 of this *Standard*.

A1.3 Definitions

Where terms appear in this *Standard* in *italics*, such terms shall have the meaning as defined in this section or as defined in AISI S100 if they are not defined in this section. Terms included in square brackets shall be specific to *Limit States Design (LSD)* terminology. Terms not italicized shall have the ordinary accepted meaning in the context for which they are intended.

Terms designated with + are common AISC-AISI terms that are coordinated between the two standards developers.

General Terms

Cellular Panel. Assemblage of one or more *profiled panels* or *profiled panel* and flat sheet interconnected to form a built-up section.

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

Connection Shear Flexibility. The property of a *connection* allowing local deflection caused by a unit load and associated with *panel* distortion or slotting, and *connection* slip or strain.

Diaphragm. Roof, floor, or other membrane or bracing system acting to transfer in-plane forces to the *lateral force-resisting system*.

Edge Panel. Full or partial width *panel* that transfers in-plane forces to the *lateral force-resisting system* of the structure along a line that generally parallels the length of the *panel*.

Exterior Support. Support located at an end of an *edge* or *interior panel*.

Insulating Concrete. A mixture of Portland cement, cellular or expanded mineral concrete aggregate, and water forming a relatively lightweight concrete. The aggregate porosity and air content provide insulating characteristics to roofs.

Interior Panel. Full or partial width *panel* that transfers in-plane forces to other *interior panels* or *edge panels*.

Interior Support. Support located at an interior zone of an *edge* or *interior panel*.

Interlocking Sidelap Connection. A *connection* formed at a vertical sheet leg (edge stiffener of *panel*) inside an overlapping sheet hem, or at vertical legs back-to-back.

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.

Nominal Shear Strength. The in-plane shear strength of the *profiled panel*, including the contribution of *connections* to support members and adjacent *panels*.

Panel. A product conforming to the definition of *profiled panel*, *cellular panel*, *perforated panel* or *perforated cellular panel* without or with concrete fill.

Perforated Cellular Panel. Assemblage of a *profiled panel* with another *profiled panel* or flat sheet including perforations.

Perforated Profiled Panel. *Profiled panel* with perforations.

Profiled Panel. Product formed from a single steel sheet into fluted profiles with top and bottom flanges connected by *web* members.

Shear Stiffness. The in-plane resistance to deformation of a panel, including the *connections*, measured by the ratio of the applied force to the corresponding displacement.

Sidelap. Joint at which adjacent *panels* contact each other along a longitudinal edge.

Sidelap Connection. A *connection* with a fastener or weld located at a *sidelap* while not penetrating

a support. Also called a *stitch connection*.

Structural Analysis+. Determination of *load effects* on members and *connections* based on principles of structural mechanics.

Structural Concrete. A mixture of Portland or other hydraulic cement, fine aggregate, coarse aggregate and water, used for structural purposes, including plain and reinforced concrete.

Support Connection. A *connection* with a fastener or weld attaching one or more sheets to supporting members.

Top Arc Seam Sidelap Welds. Arc seam welds applied at the top of an *interlocking sidelap connection*.

Wall Diaphragm. A wall, bearing or nonbearing, designed to resist lateral forces acting in the plane of the wall. Commonly referred to as a “vertical *diaphragm*” or “*shear wall*”.

A1.4 Units of Symbols and Terms

Any compatible system of measurement units is permitted to be used in the *Standard* except where explicitly stated otherwise. The unit systems considered shall include U.S. customary units (force in kilopounds (kip) and length in inches (in.)), and SI units (force in Newtons (N) and length in millimeters (mm)).

A2 Referenced Specifications, Codes and Standards

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

1. American Iron and Steel Institute (AISI), 25 Massachusetts Avenue, NW, Suite 800, Washington, DC 20001:

AISI S100-16(R2020)w/S3-22, *North American Specification for the Design of Cold-Formed Steel Structural Members With Supplement 3*

AISI S240-20, *North American Standard for Cold-Formed Steel Structural Framing*

AISI S400-20, *North American Standard for Seismic Design of Cold-Formed Steel Structural Systems*

AISI S904-17, *Standard Test Methods for Determining the Tensile and Shear Strength of Screws*

AISI S905-17, *Test Standard for Cold-Formed Steel Connections*

AISI S907-17, *Test Standard for Cantilever Test Method for Cold-Formed Steel Diaphragms*

2. ASTM International (ASTM), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA, 19428-2959:

ASTM C33/C33M-18, *Standard Specifications for Concrete Aggregates*

ASTM C330/C330M-23, *Standard Specification for Lightweight Aggregates for Structural Concrete*

ASTM C332-23, *Standard Specification for Lightweight Aggregates for Insulating Concrete*

ASTM C869-09, *Standard Specification for Foaming Agents Used in Making Preformed Foam for Cellular Concrete*

ASTM D1761-20, *Standard Test Methods for Mechanical Fasteners in Wood and Wood-Based Materials*

ASTM E488/E488M-22, *Standard Test Methods for Strength of Anchors in Concrete Elements*

ASTM E1190-21, *Standard Test Methods for Strength of Power-Actuated Fasteners Installed in Structural Members*

ASTM F1667-21a, *Standard Specification for Driven Fasteners: Nails, Spikes, and Staples*

ASTM A615/A615M-22, *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement*

ASTM A706/A706M-22a, *Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement*

ASTM A1064/A1064M-22, *Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete*

ASTM A1022/A1022M-22a, *Standard Specification for Deformed and Plain Stainless Steel Wire and Welded Wire for Concrete Reinforcement*

A2.1 Referenced Specifications, Codes and Standards for United States and Mexico

1. American Concrete Institute (ACI), 38800 Country Club Dr., Farmington Hills, MI 48331:
ACI 318-19(22), *Building Code Requirements for Structural Concrete*
2. American Institute of Steel Construction (AISC), One East Wacker Drive, Suite 700, Chicago, IL 60601-1802:
ANSI/AISC 360-22, *Specification for Structural Steel Buildings*
3. American Society of Civil Engineers (ASCE), 1801 Alexander Bell Drive, Reston, VA 20191-4400:
ASCE/SEI 7-22, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*
4. American Welding Society (AWS), 550 N. W. LeJeune Road, Miami, FL 33135:
ANSI/AWS D1.1/D1.1M-20, *Structural Welding Code – Steel*
ANSI/AWS D1.3/D1.3M-18, *Structural Welding Code – Sheet Steel*
5. American Wood Council, 1111 Nineteenth Street, NW, Suite 800, Washington, DC 20036:
ANSI/AWC NDS-2018, *National Design Specification (NDS) for Wood Construction*
TR-12, *General Dowel Equations for Calculating Lateral Connection Values*, 2015

A2.2 Referenced Specifications, Codes and Standards for Canada

1. CSA Group, 178 Rexdale Boulevard, Toronto, Ontario, Canada, M9W 1R3:
CAN/CSA A23.3-04(R2010), *Design of Concrete Structures*
CAN/CSA 086:19, *Engineering Design in Wood*
CAN/CSA S16:19, *Design of Steel Structures*
W47.1:19, *Certification of Companies for Fusion Welding of Steel*
W55.3-08 (R2018), *Certification of Companies for Resistance Welding of Steel and Aluminum*
W59-13, *Welded Steel Construction (Metal Arc Welding)*
2. National Research Council of Canada (NRC), 1200 Montreal Road, Bldg. M-58, Ottawa, Ontario, Canada, K1A 0R6:
National Building Code of Canada (NBCC), 2020

A3 Materials

Panels and cold-formed steel supports shall conform to the material requirements of AISI

S100, Section A3.

1. *Insulating concrete* aggregate shall conform to ASTM C332.
2. Foaming agent for lightweight cellular *insulating concrete* shall comply with ASTM C869.

A3.1 Materials for United States and Mexico

Hot-rolled steel supports shall conform to the material requirements of ANSI/AISC 360.

Wood supports shall conform to the material requirements of ANSI/AWC NDS.

Structural concrete shall conform to the material requirements of ACI 318.

A3.2 Materials for Canada

Hot-rolled steel supports shall conform to the material requirements of CSA S16.

Wood supports shall conform to the material requirements of CSA 086.

Structural concrete shall conform to the material requirements of CSA A23.3.

B. DESIGN REQUIREMENTS

This chapter addresses general requirements.

The chapter is organized as follows:

- B1 General Provisions
- B2 Loads and Load Combinations
- B3 Design Basis
- B4 Dimensional Limits and Considerations
- B5 Panel Properties
- B6 Fabrication and Erection
- B7 Quality Control and Quality Assurance
- B8 Evaluation of Existing Diaphragm Panels

B1 General Provisions

The design of cold-formed steel *diaphragm panels* shall be consistent with the intended behavior of the *diaphragm* in the structure and the assumptions made in the structural analysis.

B2 Loads and Load Combinations

Loads and load combinations shall be as stipulated by the *applicable building code*. Where no building code is stipulated, the loads, load combinations, and nominal loads [specified loads] shall be those stipulated as follows:

- (a) In the United States and Mexico, *ASCE/SEI 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures*; and
- (b) In Canada, *National Building Code of Canada*.

B3 Design Basis

No applicable strength or serviceability *limit state* shall be exceeded when the structure is subjected to the applicable load combinations.

Design shall be in accordance with the following methods:

- (a) *ASD* or *LRFD* – the United States and Mexico; and
- (b) *LSD* – Canada.

B3.1 Required Strength [Effect Due to Factored Loads]

The *required strength* [effect due to *factored loads*] of *panels* and *connections* shall be determined by *structural analysis* for the appropriate load combinations as stipulated in Section B2.

The *required strength* [effect due to *factored loads*] shall be noted as follows:

- $\bar{R}$ = *Required strength* [effect due to *factored loads*]
- = R in accordance with *ASD load combinations*
- = R_u in accordance with *LRFD load combinations*
- = R_f in accordance with *LSD load combinations*

B3.2 Design for Strength

Panels and their connections shall be designed to have strength such that the *available strength* [*factored resistance*], R_a , equals or exceeds the *required strength* [effect due to *factored loads*].

Design for strength shall be in accordance with:

- (a) Section B3.2.1 for *Allowable Strength Design (ASD)*,
- (b) Section B3.2.2 for *Load and Resistance Factor Design (LRFD)*, or
- (c) Section B3.2.3 for *Limit States Design (LSD)*.

B3.2.1 Allowable Strength Design (ASD) Requirements

The *required strength* shall not exceed the allowable *diaphragm* shear in accordance with Equation B3.2.1-1 for ASD:

$$R \leq R_a \quad (\text{Eq. B3.2.1-1})$$

where

$$R_a = \frac{R_n}{\Omega} \quad (\text{Eq. B3.2.1-2})$$

R = *Required strength* for ASD

R_a = *Allowable strength*

R_n = *Nominal shear strength* per unit length of *diaphragm* system as specified in Chapter D or E

Ω = *Safety factor* for *diaphragm strength* specified in Chapters C, D, E, F and G

B3.2.2 Load and Resistance Factor Design (LRFD) Requirements

The *required strength* shall not exceed the factored *diaphragm* shear in accordance with Equation B3.2.2-1 for LRFD:

$$R_u \leq R_a \quad (\text{Eq. B3.2.2-1})$$

where

$$R_a = \phi R_n \quad (\text{Eq. B3.2.2-2})$$

R_u = *Required strength* for LRFD

R_a = *Design strength*

R_n = *Nominal shear strength* per unit length of *diaphragm* system as specified in Chapter D or E

ϕ = *Resistance factor* for *diaphragm strength* specified in Chapters C, D, E, F and G

B3.2.3 Limit States Design (LSD) Requirements

The effect of *factored loads* shall not exceed the factored *diaphragm* shear resistance in accordance with Equation B3.2.3-1 for LSD:

$$R_f \leq R_a \quad (\text{Eq. B3.2.3-1})$$

where

$$R_a = \phi R_n \quad (\text{Eq. B3.2.3-2})$$

R_f = *Effect of factored loads* for LSD

R_a = *Factored resistance*

R_n = Nominal *shear resistance* per unit length of *diaphragm* system as specified in Chapter D or E

ϕ = Resistance factor for *diaphragm resistance* specified in Chapters C, D, E, F and G

B3.2.4 Shear Deflection Requirements

The design shear deflection shall not exceed the permissible shear deflection in the applicable building code in accordance with Equation B3.2.4-1. In the absence of a building code, shear deflection requirements shall be permitted to be determined in accordance with:

- a) In the United States and Mexico, ASCE/SEI 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*; and
- b) In Canada, *National Building Code of Canada*.

$$\delta_n \leq \delta_a \quad (\text{Eq. B3.2.4-1})$$

where

δ_n = Predicted *diaphragm* deflection at the design load

δ_a = Maximum permissible *diaphragm* deflection

Deflection, δ_n , is determined using *stiffness* analytical methods. *Diaphragm shear stiffness*, G' , of the *panel* shall be determined in accordance with Chapter D, E, F or G.

B3.3 Design for Diaphragm Panels

The nominal shear strength [resistance], S_n , and *diaphragm shear stiffness*, G' , shall be established by analysis (engineering mechanics) or test. The nominal [resistance] and available strength [factored resistance] of steel *diaphragm panels* that meet specified geometric and material limitations shall be permitted to be determined in accordance with Chapters D, E, F and G, as applicable.

B3.4 Design of Connections

The strength of *connection* elements subject to shear or combined shear and tension shall be designed in accordance with the provisions of AISI S100 Chapter J. Connecting elements not covered by AISI S100 shall be designed in accordance with Appendix 1 of this *Standard*. The forces and deformations used in design shall be consistent with the intended performance of the *connection* and the assumptions used in structural analysis. Self-limiting inelastic deformations of the *connections* are permitted.

The elastic *stiffness* of *connection* elements shall be designed in accordance with the provisions of Appendix 1 of this *Standard*.

The strength and *stiffness* of *connections* outside the scope of AISI S100 Chapter J or Appendix 1 shall be determined by test in accordance with AISI S100 Chapter K.

User Note:

It is important to consider the combined effects that induce *diaphragm* shear in the plane of the panels in combination with out-of-plane wind uplift (outward wind effect) on the *panels*. The *connections* of the *panels* to supports will be subject to both shear effects from the *diaphragm* action and tension from the outward wind.

B3.5 Design for Stability

Stability for *floor diaphragms*, *roof diaphragms* and *wall diaphragms (shear wall)* using *panels* as the stressed skin shall be in accordance with AISI S100 Chapter C.

B3.6 Design of Floor, Roof and Wall Diaphragm Assemblies

The design of *floor diaphragm*, *roof diaphragm* and *wall diaphragm (shear wall)* assemblies shall be in accordance with this *Standard* and the applicable materials standards for the adjoining members or materials.

B3.7 Design for Serviceability

The building structure shall be designed to perform its required functions during its expected life. Serviceability *limit states* shall be selected based on the intended function of the structure and shall be evaluated using realistic loads and load combinations. The in-plane shear deflection of *floor diaphragms*, *roof diaphragms*, or *wall diaphragm (shear wall)* assemblies using *panels* and associated support framing shall be determined with engineering mechanics using loads as specified by the *applicable building code* or project requirements and the *diaphragm shear stiffness*, G' , provisions of Chapter D, E, F or G. The shear deflection for the *panels* is also permitted to be determined by analysis following the provisions of Chapter C for both linear elastic design or non-linear design.

B3.8 Design for Fatigue

Fatigue need not be considered for seismic effects or for the effects of wind loading on typical building lateral force-resisting systems and building enclosure components. Fatigue shall be considered in accordance with AISI S100 Chapter M for cold-formed steel structural members and their *connections* subject to repeated loading within the elastic range of *stresses* of frequency and magnitude sufficient to initiate cracking and progressive failure.

B3.9 Design for Corrosion Effects

Where corrosion may impair the strength or serviceability of a structure, structural components shall be protected against corrosion or shall be designed to tolerate corrosion.

B4 Dimensional Limits and Considerations

Dimensional limits and considerations shall be as specified in Chapters D, E and F.

B5 Profiled Panel Properties

Properties of strength, gross (full) cross-sections and reduced cross-sections (cross-sectional area, moment of inertia, section modulus, radius of gyration, etc.) shall be determined in accordance with AISI S100 with conventional methods of structural design.

For perforated *panels*, the section properties shall be based on analysis or testing.

B6 Fabrication and Erection

(Reserved)

B7 Quality Control and Quality Assurance

(Reserved)

B7.1 Delivered Minimum Thickness

The delivered minimum *thickness* shall be in accordance with AISI S100.

B8 Evaluation of Existing Diaphragm Panels

(Reserved)

C. PROFILED PANEL DIAPHRAGM BY ANALYSIS

The determination of *diaphragm shear strength* and *shear stiffness* of *profiled and cellular panels*, *profiled and cellular panels with structural concrete fill* and *profiled and cellular panels with insulating concrete fill* by rational engineering analysis is permitted.

D. PROFILED PANEL DIAPHRAGM

This chapter addresses the *diaphragm shear strength* and *diaphragm shear stiffness* for *profiled panels* and *cellular panels* without concrete fill.

The chapter is organized as follows:

D1 Profiled Panels

D2 Perforated Profiled Panels

D3 Cellular Panels

D4 Perforated Cellular Panels

D5 Profiled Panels with Connections Through Insulation

D1 Profiled Panels

This section shall apply to *profiled panels* without perforated elements and within the following limits:

- (a) $0.5 \text{ in. (12 mm)} \leq \text{profiled panel depth} \leq 7.5 \text{ in. (191 mm)}$,
- (b) $0.014 \text{ in. (0.35 mm)} \leq \text{base profiled panel thickness} \leq 0.075 \text{ in. (1.91 mm)}$ for depth less than or equal to 3.0 in. (76.2 mm),
 $0.034 \text{ in. (0.85 mm)} \leq \text{base profiled panel thickness} \leq 0.075 \text{ in. (1.91 mm)}$ for depth greater than 3.0 in. (76 mm),
- (c) $33 \text{ ksi (230 MPa)} \leq \text{specified } F_y \text{ of profiled panel} \leq 80 \text{ ksi (550 MPa)}$,
 $45 \text{ ksi (310 MPa)} \leq \text{specified } F_u \text{ of profiled panel} \leq 82 \text{ ksi (565 MPa)}$,
- (d) *Profiled panel pitch* $\leq 12 \text{ in. (305 mm)}$, and
- (e) *Support fastener* $\leq 18 \text{ in. (460 mm)}$.

D1.1 Profiled Panel Diaphragm Shear Strength

The *available shear strength [factored resistance]* per unit length of a *profiled panel* shall be the least *available strength [factored resistance]* obtained from the *limit states* controlled by either *connection strength* or *panel stability* using the applicable *resistance factors* or *safety factors* in Table D1.1-1.

Table D1.1-1
Safety Factors and Resistance Factors

Support Member Type	Load Type or Combinations Including	Connection Type	Limit State					
			Connection Strength, S_{nf}			Panel Stability, S_{nb}		
			Ω (ASD)	ϕ (LRFD)	ϕ (LSD)	Ω (ASD)	ϕ (LRFD)	ϕ (LSD)
Steel	Wind	Welds	2.15	0.75	0.60	2.00	0.80	0.75
		Screws	2.00	0.80	0.75			
		All Others	Chapter G					
	Earthquake and All Others	Welds	3.00	0.55	0.40			
		Screws	2.30	0.70	0.55			
		All Others	Chapter G					
Wood	All	Screws	3.00	0.55	0.50			
		Nails						
All Others	All	All Others	Chapter G					

The nominal shear strength [resistance] per unit length of a *profiled panel* controlled by connection strength shall be the smallest of S_{ni} , S_{nc} , S_{ne} and S_{np} .

$$S_{ni} = [2A(\lambda - 1) + \beta] \frac{P_{nf}}{L} \quad (\text{Eq. D1.1-1})$$

$$S_{nc} = \left(\frac{N^2 \beta^2}{L^2 N^2 + \beta^2} \right)^{0.5} P_{nf} \quad (\text{Eq. D1.1-2})$$

$$S_{ne} = \frac{(2\alpha_1 + n_p \alpha_2) P_{nf} + n_e P_{nfs}}{L} \quad (\text{Eq. D1.1-3})$$

$$S_{np} = P_{nf} \frac{n_d}{w_t} \quad (\text{Eq. D1.1-4})$$

where the ratio of the number of support fasteners to the tributary width, n_d/w_t , shall be the resulting governing minimum combination for the *panel* under consideration.

The nominal shear strength [resistance] per unit length of a *profiled panel* controlled by panel stability shall be the smallest of S_{no} and S_{nl} .

$$S_{no} = \frac{7890}{\alpha L_v^2} \left(\frac{I_{xg}^3 t^3 d}{s} \right)^{0.25} \quad (\text{Eq. D1.1-5})$$

$$S_{nl} = P_{nw} \left(\frac{d-e}{D_d} \right) \left(\frac{1}{d} \right) \quad (\text{Eq. D1.1-6})$$

where

S_{ni} = Nominal shear strength [resistance] per unit length of diaphragm or wall diaphragm controlled by connections at interior panels or edge panels

S_{nc} = Nominal shear strength [resistance] per unit length of diaphragm or wall diaphragm controlled by support connections at the corners of interior panels or edge panels

S_{ne} = Nominal shear strength [resistance] per unit length of diaphragm or wall diaphragm controlled by connections along the edge parallel to the panel span in an edge panel and located at a diaphragm reaction line

S_{np} = Nominal shear strength [resistance] per unit length of diaphragm or wall diaphragm controlled by connections along the ends of interior panels or edge panels and into exterior supports

S_{no} = Nominal shear strength [resistance] per unit length of diaphragm or wall diaphragm controlled by panel out-of-plane buckling, kip/ft (kN/m)

S_{nl} = Nominal shear strength [resistance] per unit length of diaphragm or wall diaphragm controlled by panel local web buckling over exterior support

A = Number of exterior support connections per flute located at the sidelap at an interior panel or edge panel end

λ = Connection strength reduction factor at corner fastener, unitless

$$= 1 - \frac{D_d L_v}{240\sqrt{t}} \geq 0.7 \quad \text{for U.S. customary units} \quad (\text{Eq. D1.1-7})$$

$$= 1 - \frac{D_d L_v}{369\sqrt{t}} \geq 0.7 \quad \text{for SI units} \quad (\text{Eq. D1.1-8})$$

where

D_d = Depth of panel, in. (mm). See Figure D1.1-1

L_v = Span of panel between supports with fasteners, ft (m)

t = Base metal thickness of the panel, in. (mm)

β = Factor defining connection contribution and interaction to diaphragm shear strength per unit length

$$= n_s \alpha_s + 2n_p \alpha_p^2 + 4\alpha_e^2 \quad (\text{Eq. D1.1-9})$$

where

n_s = Number of sidelap connections along a total panel length, L , and not into supports

$$\alpha_s = \frac{P_{ns}}{P_{nf}} \quad (\text{Eq. D1.1-10})$$

where

P_{ns} = Nominal shear strength [resistance] of a sidelap connection per fastener determined in accordance with Appendix 1

P_{nf} = Nominal shear strength [resistance] of a support connection per fastener determined in accordance with Appendix 1

n_p = Number of interior supports along a total panel length, L

α_p^2 = Analogous section modulus of panel interior support connection group in an interior or edge panel

$$= \left(\frac{1}{w^2} \right) \sum x_p^2 \quad (\text{Eq. D1.1-11})$$

where

w = Panel cover width

x_p = Distance from panel centerline to an interior support connection in a panel

α_e^2 = Analogous section modulus of panel exterior support connection group in an interior or edge panel

$$= \left(\frac{1}{w^2} \right) \sum x_e^2 \quad (\text{Eq. D1.1-12})$$

where

x_e = Distance from *panel* centerline to an *exterior support connection* in a *panel*

L = Total *panel* length

N = Number of support fasteners per unit width at an *interior* or *edge panel's* end

α_1 = Measure of *exterior support* fastener group distribution across a *panel* width, w_e , at an *edge panel*

$$= \frac{\sum x_{ee}}{w_e} \quad (\text{Eq. D1.1-13})$$

where

x_{ee} = Distance from *panel* centerline to an *exterior support connection* in an *edge panel*

w_e = *Panel* cover width at the *edge panel*

α_2 = Measure of *interior support* fastener group distribution across a *panel* width, w_e , at an *edge panel*

$$= \frac{\sum x_{pe}}{w_e} \quad (\text{Eq. D1.1-14})$$

where

x_{pe} = Distance from *panel* centerline to an *interior support connection* in an *edge panel*

n_e = Number of *edge support connections* between transverse supports and along an *edge panel* length, L

P_{nfs} = Nominal shear strength [resistance] of an *edge support connection* installed parallel with an *edge panel* span and between transverse supports

n_d = Number of *support connections* at the flute bottom relative to the tributary width, w_t , along the ends of *interior* or *edge panels* and into *exterior supports*

w_t = Tributary width to any given bottom flute with *support connection(s)* along the end perpendicular to the *panel* span and located at *exterior support*

User Note:

Commentary Figure D1.1.5 provides examples on determination of n_d and w_t for a variety of *panel* configurations.

α = Conversion factor for units

= 1 for U.S. customary units

= 1879 for SI units

I_{xg} = Moment of inertia of fully effective *panel* per unit width, in.⁴/ft (mm⁴/mm)

d = *Panel* corrugation pitch, in. (mm)

e = One-half the bottom flat width of *panel* measured between points of intercept as illustrated in Figure D1.1-1, in. (mm)

s = Developed flute width per pitch, in. (mm)

= $2(e + w) + f$

(Eq. D1.1-15)

where

w = *Web* flat width of *panel* measured between points of intercept illustrated in Figure D1.1-1, in. (mm)

f = Top flat width of *panel* measured between points of intercept illustrated in Figure D1.1-1, in. (mm)

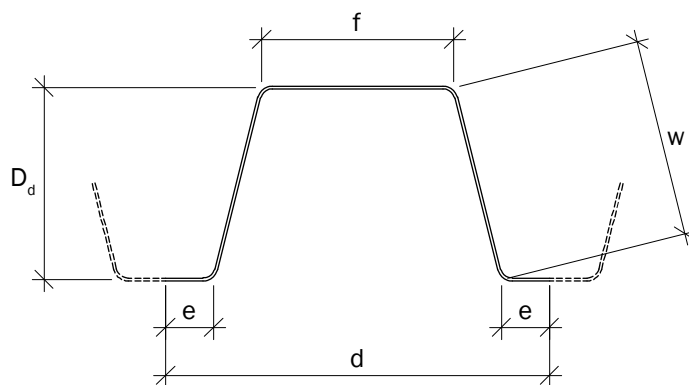


Figure D1.1-1 Panel Configuration

P_{nw} = Nominal *web crippling strength* [resistance] per *web*

$$= 4.36t^2F_y \sin \theta \left(1 - 0.04\sqrt{\frac{R}{t}} \right) \left(1 + 0.25\sqrt{\frac{N_{ext}}{t}} \right) \left(1 - 0.025\sqrt{\frac{h}{q_s t}} \right) \quad (Eq. D1.1-16)$$

where

F_y = Design *yield stress* as determined in accordance with AISI S100 Section A3.3.1

θ = Angle between plane of *web* and plane of bearing surface, $45^\circ \leq \theta \leq 90^\circ$

R = Inside bend radius

N_{ext} = Bearing length at *exterior support* (3/4 in. (19 mm) minimum)

h = Flat dimension of *web* measured in plane of *web*

q_s = Perforated *web* adjustment factor

= 1.00

D1.2 Profiled Panel Diaphragm Shear Stiffness

The *diaphragm shear stiffness*, G' , for *profiled panels* shall be calculated in accordance with Eq. D1.2-1:

$$G' = \left(\frac{Et}{2(1+\mu)\frac{s}{d} + C + \gamma_c D_n} \right) K \quad (Eq. D1.2-1)$$

where

G' = *Diaphragm shear stiffness*, kip/in. (kN/m)

E = Modulus of elasticity of steel

= 29,500 ksi, (203,000 MPa)

t = Base steel *thickness* of *panel*, in. (mm)

K = *Stiffness factor* relating support and *sidelap connection* flexibilities

= 1.00 for steel *panels* with lap-down on steel supports

= S_f/S_s for steel *panels* with lap-up on steel supports

= 0.50 for steel *panels* on wood supports

where

S_f = Structural support connection shear flexibility determined in accordance with Appendix 1, in./kip (mm/kN)

S_s = Sidelap connection shear flexibility determined in accordance with Appendix 1,

in./kip (mm/kN)

μ = Poisson's ratio for steel
= 0.3

d = Panel corrugation pitch. See Figure D1.1-1, in. (mm)

s = Developed flute width per pitch. Defined in Section D1.1, in. (mm)

C = Slip constant considering slippage at *sidelap connections* and distortion at *support connections*

$$= \left(\frac{Et}{w} \right) \left(\frac{2L}{2\alpha_3 + n_p \alpha_4 + 2n_s \frac{S_f}{S_s}} \right) S_f \quad (\text{Eq. D1.2-2})$$

where

L = Total panel length

α_3 = Measure of exterior support fastener group distribution across a panel width, w , at an interior panel

$$= \frac{\sum x_e}{w} \quad (\text{Eq. D1.2-3})$$

w = Panel cover width at the interior panel

α_4 = Measure of interior support fastener group distribution across a panel width, w , at an interior panel

$$= \frac{\sum x_p}{w} \quad (\text{Eq. D1.2-4})$$

x_p = Distance from panel centerline to an interior support connection in an interior panel

n_p = Number of interior supports along a total panel length, L

n_s = Number of sidelap connections along a total panel length, L , and not into supports

γ_c = Support factor for warping determined in accordance with Table D1.2-1

Table D1.2-1
Support Factor, γ_c

Spans	1	2	3	4	5	6	7
γ_c	1.00	1.00	0.90	0.80	0.71	0.64	0.58

D_n = Unitless warping factor considering distortion at panel ends determined using the parameters as shown in Figure D1.1-1

$$= \frac{D}{L} \quad (\text{Eq. D1.2-5})$$

where

D = Weighted average D_i value for warping across the panel width, w , in. (mm)

$$= \frac{U_1 D_1 + U_2 D_2 + U_3 D_3 + U_4 D_4}{U_1 + U_2 + U_3 + U_4} \quad (\text{Eq. D1.2-6})$$

where

U_1 = Number of corrugations having fasteners in every valley across the panel width, w

U_2 = Number of corrugations having fasteners in every second valley across the panel width, w