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The New SDI Diaphragm Design Manual

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Abstract

This article summarizes and describes in each section the changes made with the third edition publication of the Steel Deck Institute Diaphragm Design Manual (SDI-DDM). This edition is revised and adapted to include both ASD and LRFD design methods following Table D5 of the 2001 Edition of the North American Specification for the Design of Cold-Formed Steel Structural Members as modified by the Supplement 2004 to the North American Specification for the Design of Cold-Formed Steel Structural Members, 2001 Edition.

Introduction

The DDM third edition (DDM03) is a continuation of design approaches presented in earlier DDM editions with new material included for both design approaches: Allowable Stress Design (ASD) and Load and Resistance Factor Design (LRFD). The Steel Deck Institute and its member companies have sponsored developmental work and testing at West Virginia University since 1965.

This manual explains the method developed for calculating the design properties for diaphragms made with bare steel decks and concrete filled steel decks, provides examples on how to calculate the shear in diaphragm, and indicates how to use the diaphragm load tables that have been developed as design aids.

Summary of major changes made to DDM03 from its previous editions:

- DDM03 is modified for ease of use, either with LRFD or ASD;

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- Values in diaphragm load tables are nominal and must be modified by resistance or safety factors before comparing with the loads calculated with the corresponding design approach;
- Both US and SI unit system are used for calculation;
- Some formula are presented in original unitless format, then expressed separately in US and SI unit;
- Eliminates the use of "gage", instead, uses "Type" or "Deck Thickness Number" with "28, 26, 24, 22, 20, 18 and 16" to relate to the Design Thickness t;

To break down to each section, the changes and additions made to DDM03 are described hereafter with the headings set the same as the Sections in DDM03.

Section 1: Introduction

1.2 Applicable Deck Type

"Although design tables are not shown in Appendix V for decks up to and including 7.5 in. (191mm) deep, as well as cellular decks, the appropriate diaphragm values may be derived using the procedure illustrated for regular deck."

Moreover, SDI published white paper on "Deeper Steel Deck and Cellular Diaphragm" for the strength and stiffness calculations.

It is indicated that the diaphragm values for deck attached to wood structural members may be calculated using approaches similar to those in DDM03. The Metal Construction Association publication, A Primer on Diaphragm Design, addresses these cases.

1.4 Design Considerations

The design examples in DDM Appendix III address the issue of analysis and design using both LRFD and ASD code requirements. The diaphragm design load tables in Appendix V show the nominal strength of the diaphragm. These represent a departure from the previous editions of the DDM. A few definitions are listed here using a tension rod as the example to illustrate the various strength definitions.

Nominal strength is an applicable limit state: P_n=A_gF_y

LRFD
Factored nominal strength (or design strength): $\Phi P_n = \Phi A_g F_y$
Required strength is the factored applied load: $P_u = 1.2DL + 1.6LL <= \Phi P_n$

ASD
Allowable strength (or design strength): $P_n/\Omega = A_g F_y/\Omega$
Required strength is the service applied load: $P = DL + LL <= P_n/\Omega$

Section 2: Diaphragm Strength

2.1 Diaphragm Strength

It is emphasized that since the diaphragm shear is the same in either direction of the diaphragm, the direction of the deck corrugation does not affect the strength. Therefore the strength values listed in the tables in Appendix V apply to decks with corrugations in either direction.

2.3 Stability Limitations

The critical shear load of plate-like shear buckling is presented in its original form (Eq. 2.3-1 and Eq. 2.3-2), and separately with the proper unit assigned to each term in US and SI unit systems (Eq. 2.3-3 and Eq. 2.3-4).

This is typical throughout the whole manual, which is geared to serve users experienced with either US or SI unit. The user must work in with the proper unit set for each term in a formula.

2.4 Resistance Factors/ Safety Factors

The shear strengths from Section 2.2 or shown in the Load Tables are nominal values. They must be modified by resistance factors (Φ) per LRFD or by safety factors (Ω) per ASD to account for possible under-strength conditions.

Resistance and safety factors are shown in Table 2.1.

Table 2.1						
Factors of Safety and Resistance Factors for Diaphragms						
Load Type or Combinations Including	Connection Type[1]	Limit State				
		Connection Related		Panel Buckling[2]		
		USA and Mexico		USA and Mexico		
		Ω_d (ASD)	ϕ_d (LRFD)	Ω_d (ASD)	ϕ_d (LRFD)	
Earthquake	Welds	3.00	0.55	2.00	0.80	
	Screws	2.50	0.65			
Wind	Welds	2.35	0.70			
	Screws	2.35	0.70			
All Others	Welds	2.65	0.60			
	Screws	2.50	0.65			

This is based on the Supplement 2004 to the North American Specification for the Design of Cold-Formed Steel Structural Members, 2001 Edition. Notes are added further clarifying its use:

- When fastener combinations are used within a diaphragm system, the more limiting factor is used;
- Design shear, limited by panel buckling, involves resistance and safety factors differing from those of diaphragms controlled by fastener shear. The more limiting case controls;
- For mechanical fasteners other than screws, sufficient test data and calibration calculations prove that the use of power driven fasteners, such as those from Pneutek, Hilti, Buildex, is allowed in accordance with the North American Specification for the Design of Cold-Formed Steel Structural Members, and the same resistance or safety factors that control screw connected systems can be used to obtain proper diaphragm design strength;
- SDI's method of calculation for diaphragm allows the various design codes and specifications to dictate the load factors and, the test results to dictate the resistance factor and safety factor developed in accordance with the methodology of the codes and specifications.

2.5 Design Diaphragm Shear Strength

The design strength of the diaphragm ΦS_n (per LRFD) or S_n/Ω (ASD) shall be the lowest value obtained from the limit states of fastener strength (including edge fastener strength, interior and corner fastener strength) and shear buckling. Proper resistance and safety factor should be used depending on the load type, fastener type and limit state type.

2.6 Limiting Conditions

Split Panels

It is added, “Full Panel may be back-lapped and used to finish out the edge.”

Perimeter/Intermediate Connections

Designers usually choose a deck fastening pattern with a satisfying design diaphragm shear from the load table, and often neglect the importance of the determination of deck fastening at perimeter and intermediate shear transferring lines.

To ensure the transfer of the shear forces, the deck must be attached to the perimeter (flanges of the horizontal beam analogy) and intermediate members (struts and intermediate framing members transferring any differential shear).

The spacing e of perimeter/intermediate fasteners must be determined using the following equation:
$e <= Q_f/S_n$ if the full strength is needed.
With LRFD code, $e<=\Phi Q_f/S_u$ if the required strength S_u is less than the factored strength;
With ASD code, $e<=Q_f/\Omega/S_u$ if the required strength S_u is less than the allowable strength;
Where Q_f is the nominal structural connector strength, S_n is the nominal diaphragm strength; S_u is the required diaphragm strength.

To keep the same rigidity, the spacing of attachment at perimeter parallel to the deck flutes should not be larger than that for interior and side-lap fastener.

Section 3: Diaphragm Stiffness

Terminology in formulas is explained without unit specification.

Table 3.3-1 is presented in both US and SI unit systems.

It is mentioned that an alternative form of G’ is presented in Appendix IV, and its numerical value is obtained by simple substitution.

Section 4: Connections

The performance of different type of diaphragm fasteners is discussed here. Their strength and stiffness are expressed in formulas in both unit systems.

As mentioned in the Preface of DDM03, the nominal resistance for welds and screws as shear connectors are calculated according to the formulas used in the previous editions of Diaphragm Design Manual. Some of the results (Section 4.2.1 and Section 4.5, and Appendix IV Table IV) may slightly differ from the results obtained by applying the formulas shown in the 2001 Edition of the North American Specification for the Design of Cold-Formed Steel Structural Members. The Safety factors and resistance factors to be applied on the nominal diaphragm capacities shown in the tables of Appendix V have been calculated taking into account the weld and screw nominal resistance shown in Table IV of Appendix IV.

4.6 Power Driven Fasteners

Up-to-date power driven fasteners are listed with their shear strength and stiffness formulas in both unit systems. Those fasteners are:

Buildex BX-14 or BX-12
Hilti ENP2 and ENPH2, ENP2K, X-EDN19, or X-EDNK22
Pneutek SDK61-series, SDK63-series, K64-series.

4.9 Fasteners in Tension

Generally as the result of uplift pressure from wind forces, roof diaphragm fasteners are subjected to tension.

4.9.1 Arc-Spot Welds

Appendix IV Table V lists the nominal tensile resistance of some concentrically tension-loaded arc-spot welds connecting single sheet to support. According to the 2001 edition of the North American Specification for the Design of Cold-Formed Steel Structural Members, arc-spot weld on support is loaded in tension with eccentricity when placed in the side-lap flute, thus its nominal tensile strength is taken as 70% of the value from Table V, which is defined by the AISI publication.

4.9.2 Screw Connections

Based on the same AISI publication, the nominal strength of a screw loaded in tension is the lesser of the pull-out strength and the pull-over strength. Appendix IV Table VI lists the nominal tensile resistance of several screws. Side-lap screws for interconnecting panel edges only will not receive tension loads. It is noted, in Example 7A, that “Future editions of North American

Specification for the Design of Cold-Formed Steel Structural Members may modify this condition."

4.9.3 Power Driven Fasteners

The fastener manufacturers have developed connection properties for power driven fasteners. The general equations for the pins in tension are listed for the following:

Buildex BX-14 or BX-12
Hilti ENP2 and ENPH2, ENP2K, X-EDN19, or X-EDNK22
Pneutek SDK61-series, SDK63-series, K64-series.

4.9.4 Resistance Factors/Safety Factors

The nominal tension strength must be modified by the resistance factors (LRFD)/safety factors (ASD) set for construction subjected to tension.

For welded construction, Φ_u=0.6, Ω_u=2.5;

For construction with screw and power driven fasteners, Φ_u=0.5, Ω_u=3.0.

4.10 Combined Shear and Tension on Fasteners

Research at West Virginia University has concluded that there is an interaction between shear force and tension force on the diaphragm fasteners.

Different shear-tension interaction is described for arc-spot welds, screws, Hilti power driven fasteners, and Pneutek fasteners.

The interaction between shear and tension for arc-spot welds is described by

LRFD: $$\left(\frac{Q_u}{\phi Q_f}\right)^{1.5}+\left(\frac{T_u}{\phi_u T_n}\right)^{1.5} \le 1$$

If $\left(\frac{T_u}{\phi_u T_n}\right)^{1.5} \le 0.15,$ no interaction check is required

ASD: $$\left(\frac{\Omega Q}{Q_f}\right)^{1.5}+\left(\frac{\Omega_u T}{T_n}\right)^{1.5} \le 1.0$$

If $\left(\frac{\Omega_u T}{T_n}\right)^{1.5} \le 0.15,$ no interaction check is required

For screw fasteners and Hilti power driven fasteners, the shear-tension interaction is described by

If $\frac{T_u}{\phi_u T_n} > 0.15,$ $$\frac{T_u}{\phi_u T_n} + 0.85\left(\frac{Q_u}{\phi Q_f}\right) \le 1$$

If $\frac{\Omega_u T}{T_n} > 0.15,$ $$\frac{\Omega_u T}{T_n} + 0.85\left(\frac{\Omega Q}{Q_f}\right) \le 1$$

For Pneutek fasteners the shear-tension interaction is described by

$$\frac{Q_u}{\phi Q_f} + \left(\frac{T_u}{\phi_u T_n}\right)^2 \le 1 \qquad \frac{\Omega Q}{Q_f} + \left(\frac{\Omega_u T}{T_n}\right)^2 \le 1$$

If $\left(\frac{T_u}{\phi_u T_n}\right)^2 \le 0.15,$ no interaction check is required

If $\left(\frac{\Omega_u T}{T_n}\right)^2 \le 0.15,$ no interaction check is required

Example 7 in DDM Appendix III presents the check of shear-tension interaction, and Example 7A shows how the diaphragm shear is affected when tension is introduced.

Section 5: Filled Diaphragms

5.3 Structural Concrete

Minimum shear for structural concrete filled floor deck diaphragm, having at least cover depth dc=2.5in. (65mm) and 6x6-W1.4xW1.4 (152x152-MW9.1xMW9.1) mesh reinforcement, is expressed in US and SI unit systems and for normal and lightweight concrete.

5.4 Perimeter Connections

Similar to Section 2.6, the perimeter connection spacing shall be determined with structural connector nominal shear strength, required linear diaphragm shear and resistance or safety factors for LRFD or ASD code respectively.

However since the concrete fill may add significantly to the strength within the system, it may be necessary to increase the number or strength of perimeter connectors in order to develop the required strength.

Intermediate side-lap fastener in concrete filled diaphragm add little to the diaphragm shear strength once the concrete is cured. Reasonable maximum spacing of side-lap fastener is imposed to limit the differential deflection between adjacent panels, which can result in concrete leakage. The 30 in. (750mm) maximum spacing is a practical limit from common practice. Section 2.6 gives further comments on perimeter spacing.

5.6 Stiffness and deflection

Filled diaphragm stiffness is expressed in both unit systems, and in the simplified form.

5.7 Resistance Factors/Safety Factors

The combination of steel deck and the covering material for filled diaphragm can lead to increased variability. Safety factor of 3.25 is kept, and resistance factor of 0.5 is selected to modify the nominal diaphragm shear capacity shown in the Appendix V Load Tables.

Appendix I & II Symbols / References

Some terminologies are assigned with new definition, such as P_u, Q_u, S_u and T_u, which are required factored values for LRFD. Some are first time introduced, such as P_n, S_n and T_n, which are in nominal values; Φ, Φ_u as resistance factor, Ω, Ω_u as safety factor; β as fastener pattern factor or panel buckling factor.

New references are added to Appendix II, which are listed as **(23)**, **(37)**, **(38)** and **(39)**.

Appendix III Shear Diaphragm Examples

Example 6 Strength Evaluation

The diaphragm design shear is calculated according to LRFD and ASD with the resistance factor/safety factor assumed for wind load. The design load is then compared to the panel buckling to see if the latter governs over the strength.

The strength of the diaphragm is also developed from free body diagrams along with the principles outlines in Section 2.

Example 7 Roof Design

There are many references and codes to determine the wind loads on building. The detailed calculation of wind load is not shown, only the line loads resulted on roof diaphragm are given.

The required diaphragm strength and the design strength are calculated with LRFD or ASD as design code. Minimum Design Loads for Buildings and Other Structures (ASCE 7-98) is used as reference and the wind load factor is 1.6.

Stiffness is calculated using the formula with simple substitution of the factors from the appropriate tables in Appendix IV and V.

Deflection of diaphragm is calculated using service shear diagram area method.

It is added the verification under combination of diaphragm shear and uplift. SDI publication "Roof Deck Construction Handbook" is referenced to differentiate the type and strength of support weld in side-lap flute from the concentrically loaded welds. K factor measures the effective fasteners per deck cover width noting that the edge fasteners may be shared with adjacent panels. Fastener pattern factor β is introduced as effective support fastener per unit cover width. Each fastener on interior purlins then has an effective tributary area of l_v/β. Then tension on each fastener is easily obtained in both codes with a given uplift pressure. The individual connectors will exhibit shear ratios in the same manner as the diaphragm shears. Equations in Section 4.10 are used for tension-shear interaction check. Different fastener pattern or type may be selected if the tension term is too large and the interaction fails.

Further discussion of diaphragm as a simply supported uniform loaded beam shows that the diaphragm shears are identical in values on orthogonal faces.

Example 7A Roof Deck Design for Uplift and Shear Interaction

With a different use of the fastener shear and tension interaction limit, this example demonstrates how the diaphragm shear capacity is influenced with the appearance of tension on diaphragm fasteners. Both types of support fastener, weld and screw, are investigated.

Example 11 Rigid Frame

Analysis by the stiffness methods is added.

Example 12 Rigid Frames

Analysis by the stiffness method and that by the truss analogy are added.

Example 13 Split Level Diaphragm

Stiffness method is added to solve for shear distribution in the split-level diaphragm.

Appendix IV Typical Fastener Layout/Warping Factor Development/Diaphragm Design Tables

Typical Fastener Layout

Typical fastener layouts for composite decks are added.

General Stiffness Equations

Simplified equations for the stiffness of bare deck and filled deck are shown, together with the tables listing the numerical values of factor K_1, K_2, K_3 and K_4 for substitution to the stiffness equations.

General Stiffness Equations

BARE DECKS: $$G' = \frac{K_2}{K_4 + \frac{0.3D_{xx}}{\ell_v} + 3K_1 \ell_v}$$ (for deck with triple span condition)

FILLED DECKS: $$G' = \frac{K_2}{K_4 + 3K_1 \ell_v} + K_3$$

For US units, ℓ_v is purlin or joist spacing in feet.

For SI units, ℓ_v is purlin or joist spacing in meters.

D_{xx}: select the appropriate value of D_{xx} from Table I, ft, or Table I-M, m.

K_1: see load tables for the value, ft^{-1}

{To convert to m^{-1}, multiply K_1 from load table by 3.387. i.e. (3.281) $\left[\frac{210000\ MPa}{(29500\ ksi)\ (6.895)}\right]$}

Type	Thickness		K_2	
28	0.0149 in.	0.38 mm	440 kip/in.	80 kN/mm
26	0.0179 in.	0.45 mm	528 kip/in.	95 kN/mm
24	0.0239 in.	0.60 mm	705 kip/in.	126 kN/mm
22	0.0295 in.	0.75 mm	870 kip/in.	158 kN/mm
20	0.0358 in.	0.91 mm	1056 kip/in.	191 kN/mm
18	0.0474 in.	1.20 mm	1398 kip/in.	252 kN/mm
16	0.0598 in.	1.52 mm	1764 kip/in.	319 kN/mm

Concrete type	f'_c		K_3	
insulating concrete	125 psi	0.860 MPa	260 kip/in.	46 kN/mm
structural concrete	3000 psi	21 MPa	2380 kip/in.	430 kN/mm

Deck profile	K_4
WR,IR,NR	3.78
DR	4.31
9/16" x 2.5" form deck	3.20
1.5" x 6" composite deck	3.78
2" x 12" composite	3.14
3" x 12" composite deck	3.54

Table I and I-M list typical factors to reflect deck profile, fastener pattern, and warping.

Table II and II-M list the Moment of Inertia for SDI generic profiles used in DDM03.

Table III and III-M list deck panel yield, ultimate strength and modulus of elasticity.

Table IV and IV-M list nominal shear strength and flexibility of typical fasteners used at support and side-lap.

Table V and V-M list the nominal tensile strength of concentrically loaded arc-spot welds.

Table VI and VI-M list the nominal tensile strength of screws.

Table VII and VII-M list the nominal tensile strength of Buildex power driven fasteners used in DDM03.

Table VIII and VIII-M list the nominal tensile strength of Pneutek power driven fasteners used in DDM03.

Table IX and IX-M list the nominal tensile strength of Hilti power driven fasteners used in DDM03.

Table X and X-M list the fastener pattern factors β with different deck profile and fastener pattern for weld and mechanical fastener.

Appendix V Load Tables

The load tables are showing nominal values, which must not be used without applying the proper resistance or safety factors.

For LRFD, the table value must be multiplied by a resistance factor when comparing to force evaluated using Load and Resistance Factor Design.

For ASD, the table value must be divided by a safety factor when comparing to the forces evaluated using Allowable Stress Design.

Nominal diaphragm shears due to panel buckling are tabulated to check whether it governs over the connector strength for diaphragm design.

Shaded values or no values do not comply with the minimum spacing for side-lap connections and shall not be used except with properly spaced side-lap connections. Shade values are the rows with 0 side-lap connection, and can be referred conservatively for diaphragm with button punched side-laps.

For each design thickness and combination of support/side-lap fastening:

1.5 in. (38mm), 2 in. (51mm) and 3 in. (76mm) composite deck load table is shown with normal or lightweight structural concrete fill;

9/16in. (14mm) x 2 ½in. (64mm) form deck load table is shown with normal or lightweight structural concrete fill, and with insulating concrete assembled as Type I and Type II.

A user-friendly table of contents for diaphragm load tables is added on page AV-4.

A composite deck diaphragm load table is shown at the end of this paper as an example.

Conclusion

The changes made to DDM03 meet the designer's needs of conception using either ASD or LRFD code in either U.S. or SI units. The diaphragm shear values are tabulated in nominal values so to allow designers to apply safety or resistance factors according to the design code selected. Further research is required to justify these factors as listed in Supplement 2004 to the North American Specification for the Design of Cold-Formed Steel Structural Members, 2001 Edition.

Example 7A takes into account the load eccentricity on the support welds in side lap flutes, and considered no reduction for edge screws in tension. Future editions of the North American Specification for the Design of Cold-Formed Steel Structural Members may modify this condition.

SDI published white paper on "Deeper Steel Deck and Cellular Diaphragm" for the strength and stiffness calculation. Review of previous test results showed that the SDI method has merit for use in evaluating strength and stiffness of cellular diaphragms with flat plate or mirror image closures, and of long span decks. American Iron and Steel Institute (AISI) and SDI jointly plan some more tests to be done for Deep Deck diaphragm action study.

Appendix. - References

1. Luttrell, L. D., Deeper Steel Deck And Cellular Diaphragms (DSDCD), Steel Deck Institute, 2005.

2. Luttrell, L. D., Diaphragm Design Manual Second Edition (DDM02), Steel Deck Institute, 1991.

3. Luttrell, L. D., Diaphragm Design Manual Third Edition (DDM03), Steel Deck Institute, 2004.

4. Luttrell, L. D., Steel Deck Institute Diaphragm Design Manual First Edition (DDM01), 1981.

5. Minimum Design Loads in Buildings and Other Structures, ASCE 7-98, American Society of Civil Engineers.

6. North American Specification for the Design of Cold-Formed Steel Structural Members, American Iron and Steel Institute, CANACERO, Canadian Standards Association, 2001.

7. Roof Deck Construction Handbook (RDCH), Steel Deck Institute, 2000.

8. Supplement 2004 to the North American Specification for the Design of Cold-Formed Steel Structural Members, 2001 Edition, American Iron and Steel Institute, CANACERO, Canadian Standards Association.

Appendix. - Notation

A_g	Tension rod cross-section area
DL	Dead loads
e	Perimeter edge fastener spacing
F_y	Panel yield strength
K	Number of fasteners per panel width taking into account eccentric loading.
LL	Live loads
L_v	Purlin or joist spacing
P_n	Nominal diaphragm strength
P_u	Required factored diaphragm strength for LRFD
Q	Fastener required allowable shear strength
Q_f	Fastener strength, panel-to-frame
Q_u	Fastener required factored shear strength
S_n	Nominal linear diaphragm shear
S_u	Required factored linear diaphragm shear for LRFD
t	Base sheet metal thickness
T	Fastener required allowable tensile strength
T_u	Fastener required factored tensile strength
β	Fastener pattern factor
Φ, Φ_u	Resistance factor
Ω, Ω_u	Safety factor

COMPOSITE DECK
t = design thickness = 0.0358"
SUPPORT FASTENING: 5/8" puddle weld or equivalent
SIDE-LAP FASTENING: 5/8" puddle weld or 1 1/2" long fillet weld

ϕ (EQ): 0.55 Ω (EQ): 3.00 ϕ (FILLED, EQ): 0.50 Ω (FILLED, EQ): 3.25
ϕ (WIND): 0.70 Ω (WIND): 2.35 ϕ (FILLED, WIND): 0.50 Ω (FILLED, WIND): 3.25
ϕ (Other): 0.60 Ω (Other): 2.65 ϕ (FILLED, Other): 0.50 Ω (FILLED, Other): 3.25

TYPE OF FILL	FASTENER LAYOUT	SIDE-LAP CONN./SPAN	NOMINAL SHEAR STRENGTH, PLF SPAN, FT										K1
			4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	
1 1/2" x 6" NO FILL (BARE DECK)	36/4	0	725	575	470	395	340	300	270	245	225	205	0.803
		1	1020	850	730								0.394
		2	1250	1070	930	820	730	645					0.261
		3	1425	1250	1105	985	885	800	730	670	615 *		0.195
		4	1560	1395	1250	1125	1020	930	855	790 *	730 *	680 *	0.156
		5	1660	1510	1375	1250	1145	1050	970 *	895 *	835 *	780 *	0.130
		6	1735	1600	1475	1355	1250	1155 *	1070 *	1000 *	930 *	875 *	0.111
		8	1840	1735	1630	1525	1425 *	1335 *	1250 *	1175 *	1105 *	1040 *	0.086
2" x 12" NO FILL (BARE DECK)	36/4	0	715	560	455	385	335	300	270	245	225	205	0.803
		1	1020	850	715								0.394
		2	1250	1070	930	820	725	645					0.261
		3	1425	1250	1105	985	885	800	730	670	615 *		0.195
		4	1560	1395	1250	1125	1020	930	855	790 *	730 *	680 *	0.156
		5	1660	1510	1375	1250	1145	1050	970 *	895 *	835 *	780 *	0.130
		6	1735	1600	1475	1355	1250	1155 *	1070 *	1000 *	930 *	875 *	0.111
		8	1840	1735	1630	1525	1425 *	1335 *	1250 *	1175 *	1105 *	1040 *	0.086
3" x 12" NO FILL (BARE DECK)	36/4	0	680	535	445	385	335	300	270	245	225	205	0.803
		1	1020	850	705								0.394
		2	1250	1070	930	820	725	645					0.261
		3	1425	1250	1105	985	885	800	730	670	615 *		0.195
		4	1560	1395	1250	1125	1020	930	855	790 *	730 *	680 *	0.156
		5	1660	1510	1375	1250	1145	1050	970 *	895 *	835 *	780 *	0.130
		6	1735	1600	1475	1355	1250	1155 *	1070 *	1000 *	930 *	875 *	0.111
		8	1840	1735	1630	1525	1425 *	1335 *	1250 *	1175 *	1105 *	1040 *	0.086
2 1/2" NW CONC. (ABOVE DECK)	36/4	0	5680	5525	5420	5345	5290	5250	5215	5185	5160	5140	0.803
		1	6070	5835	5680								0.394
		2	6460	6150	5940	5795	5685	5595					0.261
		3	6855	6465	6205	6020	5880	5770	5685	5615	5555		0.195
		4	7245	6775	6465	6240	6075	5945	5840	5755	5685	5625	0.156
		5	7635	7090	6725	6465	6270	6120	5995	5900	5815	5745	0.130
		6	8030	7405	6985	6690	6465	6290	6155	6040	5945	5865	0.111
		8	8810	8030	7510	7135	6860	6640	6465	6325	6205	6105	0.086
2 1/2" LW CONC. (ABOVE DECK)	36/4	0	4015	3860	3755	3685	3630	3585	3550	3520	3500	3480	0.803
		1	4405	4175	4020								0.394
		2	4800	4485	4280	4130	4020	3935					0.261
		3	5190	4800	4540	4355	4215	4105	4020	3950	3890		0.195
		4	5580	5115	4800	4580	4410	4280	4175	4090	4020	3960	0.156
		5	5970	5425	5060	4800	4605	4455	4335	4235	4150	4080	0.130
		6	6365	5740	5325	5025	4800	4630	4490	4375	4280	4200	0.111
		8	7145	6365	5845	5475	5195	4975	4805	4660	4545	4440	0.086

* NOMINAL SHEAR SHOWN ABOVE MAY BE LIMITED BY SHEAR BUCKLING. SEE TABLE BELOW.
THE SHADED VALUES DO NOT COMPLY WITH THE MINIMUM SPACING REQUIREMENTS FOR SIDE-LAP CONNECTIONS AND SHALL NOT BE USED EXCEPT WITH PROPERLY SPACED SIDE-LAP CONNECTIONS.
WHEN FILLED DIAPHRAGMS ARE USED, IT MAY BE NECESSARY TO INCREASE THE NUMBER, OR STRENGTH, OF THE PERIMETER CONNECTIONS TO DEVELOP THE VALUES SHOWN IN THE TABLE. CHECK SECTION 5.4.
REFER TO THE 0 SIDE-LAP CONNECTION ROWS FOR DESIGN SHEAR OF DIAPHRAGMS WITH BUTTON PUNCHED SIDE-LAPS.

ϕ (Buckling): 0.80 Ω (Buckling): 2.00

TYPE OF DECK NO FILL	FASTENER LAYOUT	I in^4 / ft	NOMINAL SHEAR DUE TO PANEL BUCKLING (S_n), PLF / SPAN, FT									
			4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0
1 1/2" x 6"	36/4	0.212	4755	3040	2110	1550	1185	935	760	625	525	450
2" x 12"	24/3 & 36/4	0.420	8320	5325	3695	2715	2080	1640	1330	1100	925	785
3" x 12"	24/3 & 36/4	0.993	15395	9855	6840	5025	3850	3040	2460	2035	1710	1455

NOTE: ASD Required Strength (Service Applied Load) <= Minimum [Nominal Shear Strength / Ω (EQ or WIND), Nominal Buckling Strength S_n / Ω (Buckling)]
LRFD Required Strength (Factored Applied Load) <= Minimum [ϕ (EQ or WIND) x Nominal Shear Strength, ϕ (Buckling) x Nominal Buckling Strength S_n]