In Plane Diaphragm Shear

Diaphragm Shear and Flexibility

Diaphragm shear and flexibility for steel deck diaphragms have been developed through a combination of fastener strength testing, full-scale diaphragm shear testing, and analytic equations. The steel deck panels, produced by ASC Steel Deck, can be used in assemblies not covered in this catalog using the design methods in the *Steel Deck Institute, Diaphragm Design Manual*, 3rd Edition.

Allowable and Factored Diaphragm Shear Tables

The allowable and factored diaphragm shears presented in the tables are based on load combinations, including earthquake (seismic) loading in accordance with Section D5 of the North American Specification for the Design of Cold-Formed Steel Structural Members. The values above and to the right in the shaded areas, as indicated on the partial table (*see Figure 1.9.3)*, indicate that plate-like buckling governs for the span condition listed. For wind load combinations, the nominal diaphragm shear may be backed out of the allowable or factored shear, the appropriate factor from Table D5 for wind loading can be applied.

ASD LRFD

$$S_a = \frac{S_n}{\Omega} \qquad S_f = \phi S_n$$

- S_a Allowable diaphragm shear, plf
- S_f Factored diaphragm strength, plf
- S_n Nominal diaphragm strength, plf
- Φ Resistance factor for LRFD, per Section D5 of the North American Specification for the Design of Cold-Formed Steel Structural Members
- Ω Safety Factor for ASD, per Section D5 of the North American Specification for the Design of Cold-Formed Steel Structural Members

Using Diaphragm Shear and Flexibility Tables

The allowable or factored diaphragm shear (pounds per lineal foot) and flexibility factor (micro inches per pound) are presented in the tables. The shear and flexibility calculations are based on the following variables:

1. Deck panel
2. Deck gage
3. Deck vertical load span (support spacing)
4. Connection type to supports
5. Connection to support pattern
6. Side lap connection type
7. Side lap connection spacing

In addition to the above conditions the flexibility is also affected by the following:

8. End lap condition, end lapped or butted
9. Ratio of span to sheet length

Deck panels and gage are generally selected using the vertical load requirements for a given span. The connection type to supports is based on the supporting member thickness. The attachment pattern, the side lap connection type and spacing are generally selected to meet the diaphragm shear demand on the diaphragm. The deck panel gage may need to be increased to meet high diaphragm shear demands. It is generally more cost effective to exhaust deck attachment options to achieve a required diaphragm shear capacity before increasing the gage of the deck *(see Figure 1.9.3)*

TABLE D5
Factors of Safety and Resistance Factors for Diaphragms

<table>
<tr><th rowspan="4">Load Type or Combinations I Including</th><th rowspan="4">Connection Type[1]</th><th colspan="6">Limit State</th></tr>
<tr><th colspan="3">Connection Related</th><th colspan="3">Panel Buckling[2]</th></tr>
<tr><th colspan="2">USA and Mexico</th><th>Canada</th><th colspan="2">USA and Mexico</th><th>Canada</th></tr>
<tr><th>Ω_d (ASD)</th><th>Φ_d (LRFD)</th><th>Φ_d (LSD)</th><th>Ω_d (ASD)</th><th>Φ_d (LRFD)</th><th>Φ_d (LSD)</th></tr>
<tr><td rowspan="2">Earthquake</td><td>Welds</td><td>3.00</td><td>0.55</td><td>0.55</td><td rowspan="6">2.00</td><td rowspan="6">0.80</td><td rowspan="6">0.75</td></tr>
<tr><td>Screws</td><td>2.50</td><td>0.65</td><td>0.65</td></tr>
<tr><td rowspan="2">Wind</td><td>Welds</td><td rowspan="2">2.35</td><td rowspan="2">0.70</td><td rowspan="2">0.70</td></tr>
<tr><td>Screws</td></tr>
<tr><td rowspan="2">All Others</td><td>Welds</td><td>2.65</td><td>0.60</td><td>0.60</td></tr>
<tr><td>Screws</td><td>2.50</td><td>0.65</td><td>0.65</td></tr>
</table>

Note: Panel buckling is out-of-plane and not local buckling at fasteners

Figure 1.9.1: **TABLE D5 FROM THE 2004 SUPPLEMENT & 2007 NORTH AMERICAN SPECIFICATION FOR THE DESIGN OF COLD-FORMED STEEL STRUCTURAL MEMBERS**

Diaphragm Shear and Flexibility of Cellular Panels

Specific diaphragm shear and flexibility tables are available for some of our cellular deck panels. For those cellular products that do not have specific tables, refer to the diaphragm shear and flexibility of the non-cellular version of the profile, using the gage of the flat bottom section of the cellular product. When designing based on the non cellular version of the panel the actual shear of the cellular panel is higher the flexibility is lower. The shear is higher because the connection to supports includes both the bottom flat sheet and the top profile sheet which increases the strength of the connection. The cellular is stiffer than the non-cellular version of the profile because the flat bottom panel is much stiffer than the profile section alone.

End Lap or Butted Deck

The end lapping of deck panels verses butted deck panels does not affect diaphragm shear strength. The end lap does affect the diaphragm shear stiffness by eliminating most of the end warping for the deck flutes due to diaphragm shear. End lapping stiffens the diaphragm, reducing the in-plane deflection of the roof structure. End lapping also reduces the number of connections to supports at the sheet ends, leading to reduced erection costs. Butted deck panels ends are necessary in certain conditions, such as at valleys or ridges on steep slope roofs.

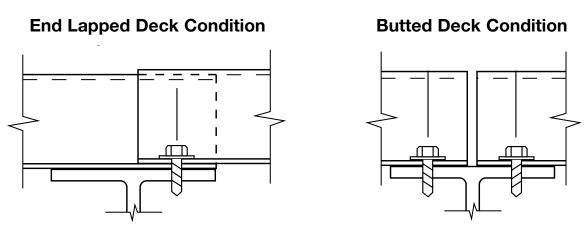

Figure 1.9.2: **END LAP AND BUTTED DECK**

Fastener Selection to Supporting Members

The fastening of deck to the supporting members has an impact of the diaphragm shear. The higher shear of the fastener, the higher the shear for a given sheet of deck. Welds produce high shears. Power actuated fasteners (nails/pins) can produce a wide range of shears depending on the support member thickness and the selected fastener. Self drilling screws produce

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How to Read Diaphragm Shear Table

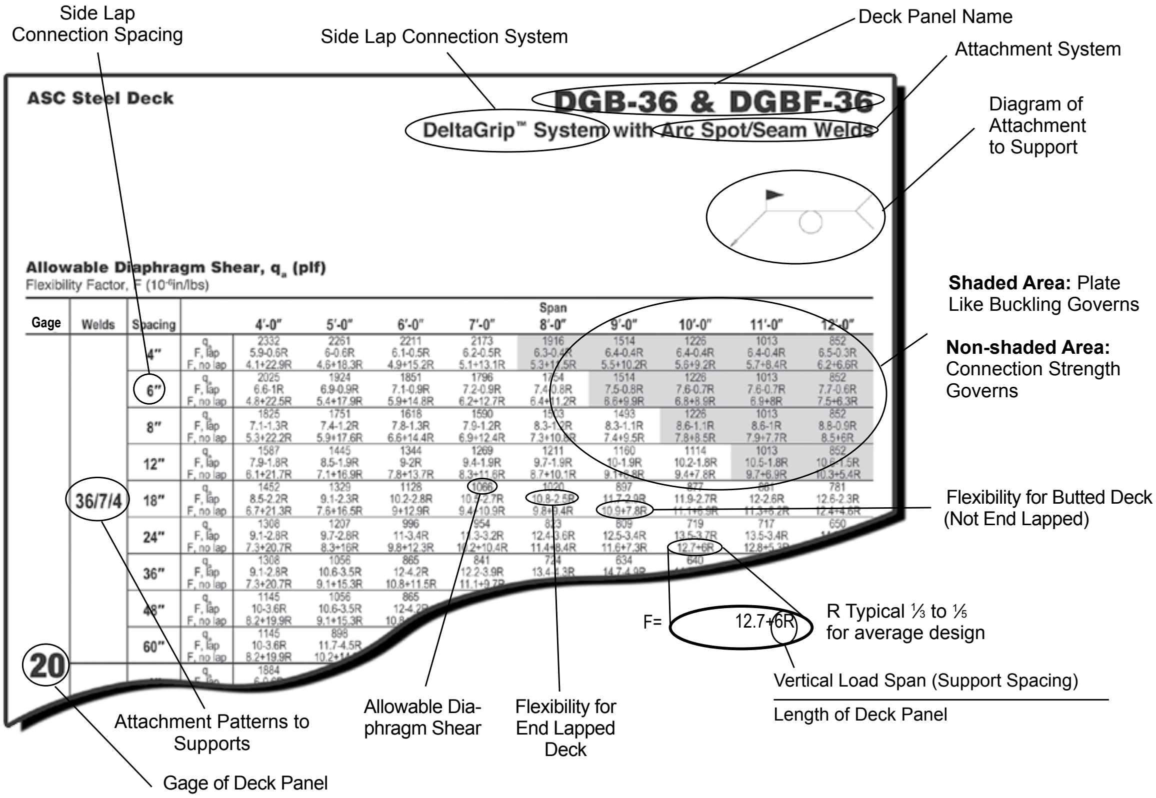


Figure 1.9.3: **SAMPLE OF DIAGRAM SHEAR AND FLEXIBILITY TABLE**

shears on the lower end of the mechanical fastener range. The fastening system must be compatible with the support member thickness and deliver the required performance for the diaphragm. Refer to the fastener section of the catalog for more information.

Side Seam/Side Lap Fasteners

All standard steel deck panels have a standing seam interlock which is suitable for button punch, top seam welds and our revolutionary DeltaGrip® side lap fastening system, (for panels designated DG). The button punch side lap fastener is the most cost effective, yet provides the lowest diaphragm shear capacity. Welded top seam fastening is the least cost effective but offers significantly higher diaphragm shear capacities than button punching. The most efficient and cost effective side lap fastener type is the DeltaGrip system. This system provides high diaphragm shear capacities similar to the top seam weld with installation costs equivalent to button punching.

Another side lap fastening option is the use of screws, with nestable side lap steel deck panels. Side lap screws provide moderate diaphragm shear capacities compared to low shear button punches and the high shear DeltaGrip systems. The installation cost of screws is greater than button punching and much less expensive than top seam welding.

Side Seam/Side Lap Fastener Spacing

The first side lap connection from the supporting member shall not be more than one-half the specified spacing of the side lap connections, (*see Figure 1.9.4*). No side lap connection should be installed directly over the center line of the support member.

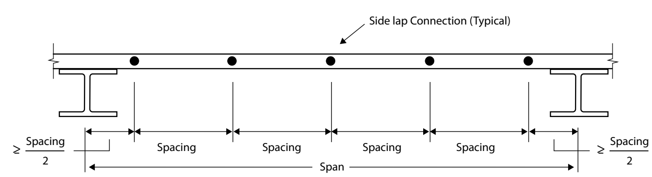


Figure 1.9.4: **SIDE LAP FASTENER SPACING**

Diaphragm Boundary Fasteners to Supports

Diaphragm boundary connection to supports, perpendicular to the deck, should be the specified attachment pattern for the steel deck panels.

Diaphragm boundary fastener spacing, parallel with panel ribs, shall not exceed the spacing determined by dividing the required diaphragm shear demand by the fastener shear strength. Connector shear strengths are presented in Section 1.11.12 and 1.11.13, Support Fastening.

$$Spacing(in) = \frac{Q_{fa}}{s_a}\left(\frac{12in}{ft}\right) \qquad Spacing(in) = \frac{Q_{ff}}{s_f}\left(\frac{12in}{ft}\right)$$

Q_{fa} Allowable fastener strength using safety factor from AISI S100-2007 Table D5
Q_{ff} Factored fastener strength using resistance factor from AISI S100-2007 Table D5
S_a Allowable shear diaphragm demand
S_f Factored shear diaphragm demand

At skew cut conditions, the minimum number of fasteners is determined based on the location of the fasteners in the ribs per the perpendicular attachment schedule. The average spacing of the fastener per sheet shall not be less than the spacing of the parallel boundary fasteners. Fasteners may need to be doubled up in some flutes to achieve this. (*See figure 1.10.1)*

In Plane Diaphragm Flexibility

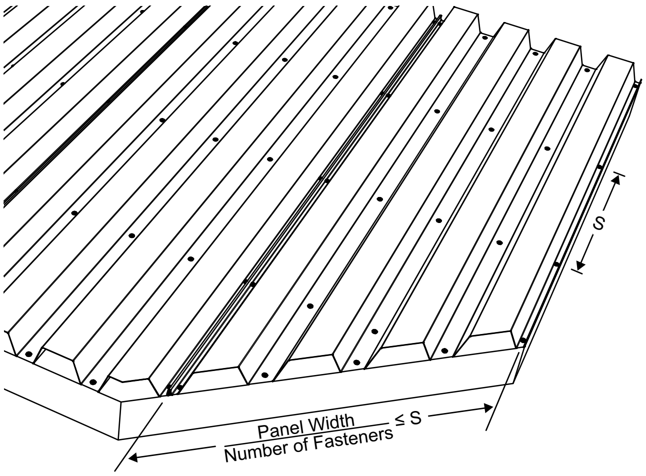


Figure 1.10.1: **SKEW DIAPHRAGM**

Diaphragm Shear Zoning

Steel deck diaphragms may be zoned based on shear demand on the diaphragm to create the most economical roof structure. This may not be practical for every building, but many rectangular large roof structures lend themselves to zoning. The deck panel along the collectors will have the highest shear demand dropping off toward the middle of the diaphragm. The deck gage and attachment pattern can be reduced as the shear demand in the diaphragm diminishes (*see Figure 1.10.2*).

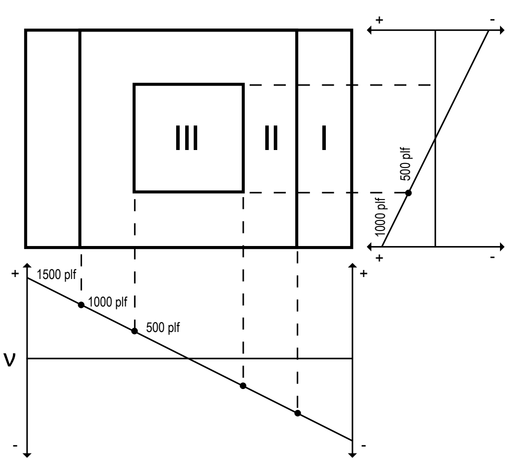


Figure 1.10.2: **DIAPHRAGM SHEAR ZONING**

Diaphragm Deflection

Diaphragms in plane deflections should be based on the shear deflection of the diaphragm. For diaphragms that do not have a large aspect ratio of length to depth, flexural deflection should not be considered. Flexural deflection equations based on slender beams do not apply to deflection of deep beams, which are generally considered beams with a length to depth ratio of 5:1 or less. Diaphragms with length to depth ratios greater than 5:1 probably do not meet the requirements for flexural deflections because the diaphragm is orders of magnitude more flexible than the diaphragm cords.

Typical lengths of steel deck panels that are safe and efficient for erection are in the 20 to 35 foot range. For erection safety, 3 spans sheets are the desirable minimum sheet length. A minimum 3 span condition should be specified because single and double spans are required for layout in most buildings. For 8 foot spans, this would be 24 feet long. For lighter gage panels with closer support spacings, such as 6 feet, typical sheet lengths will be 30 feet. For design purposes a ratio of span to length, R, of ⅓ to ⅕ is appropriate for general design.

$$F = \#.\# + \#.\# R \qquad R = \frac{L_v}{L}$$

Example:
DGB-36
20 gage
36/7/4 attachment pattern
DeltaGrip® spacing of 12 inches
Vertical load span of 5 feet F=7.1+19.6R
Assume R = 1/5, a 25 foot long panel with 5 foot vertical load span

$$F = 7.1 + 19.6R = 7.1 + 19.6(1/5) = 11$$

F = Diaphragm stiffness in micro inches per lbs
L_v = Vertical load span, which is the support spacing
L = Deck panel length, which is a multiple of the vertical load span

Figure 1.10.3: **DIAPHRAGM STIFFNESS FACTOR**

Diaphragm Deflection Concept

The deflection of a diaphragm that is zoned for shear can be approximated by summing the deflection of each deck zone, based on the diaphragm stiffness of each zone (*see Figure 1.10.4)*. For zone 3 in the figure, the diaphragm stiffness of the least stiff zone is applied to the entire building depth.

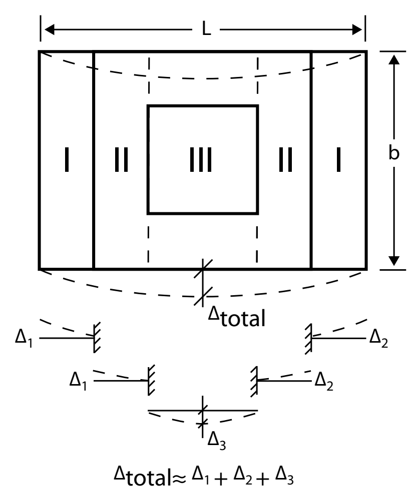


Figure 1.10.4: **DIAPHRAGM DEFLECTION CONCEPT**

In Plane Diaphragm Flexibility

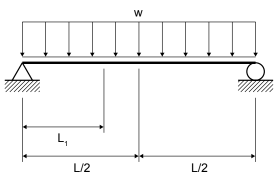
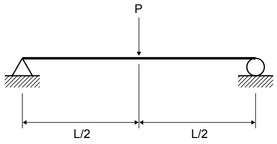
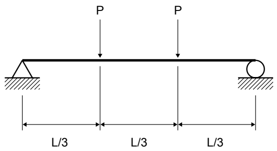
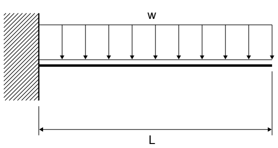
Diaphragm Deflecton Equations

Determination of Diaphragm Shear (Web) Deflections shall be based on the flexibility factor, F, in 10-6in/lbs and equations of engineering mechanics. The flexibility factor is determined by one of the following equations, in the format presented below.

Relationship between Flexibility Factor and Stiffness Factor

$$F = \frac{1000}{G'}$$

Figure 1.10.5: **DIAPHRAGM SHEAR DEFLECTION EQUATIONS**

Type of Loading	Loading Condition	Shear Deflection	Load Diagram
Simple Beam at Center	Uniform Load, w	$\Delta_w = \frac{wL^2}{8bG'}$	
Simple Beam at L_1	Uniform Load, w	$\Delta_w = \frac{q_{ave}L_1}{G'}$	
Simple Beam at Center	Point Load, P	$\Delta_w = \frac{PL}{4bG'}$	
Simple Beam at ⅓ Points	Point Load, P	$\Delta_w = \frac{PL}{3bG'}$	
Cantilever Beam at End	Uniform Load, w	$\Delta_w = \frac{WL^2}{2bG'}$	
Cantilever Beam at End	Uniform Load, P	$\Delta_w = \frac{PL}{bG'}$	

b = Depth of diaphragm (ft)

F = Flexibility factor (micro in/lbs)

G' = Stiffness factor (kips/in)

L = Diaphragm length (ft)

L_1 = Distance to point where deflection is calculated (ft)

P = Concentrated load (lbs)

q_{ave} = Average diaphragm shear (lbs/ft)

w = Uniform load (lbs/ft)

Δw = Web deflection