Shear and Uplift Diaphragm Interaction
Design Aid Tutorial & Comments

Scope: This design aid provides the "field of the roof" diaphragm shear resistance. Performance of any diaphragm depends on the proper design and installation of perimeter details. The designer must address these details.

Design Philosophy: The structural fasteners are worked by both diaphragm shears and uplift pressures so interaction occurs at these fasteners. Since the two elements that are attached by side-lap fasteners are of approximately equal stiffness and are not attached to supports, they should deflect about the same. The side-lap fasteners are subject to minimal uplift strain. There is no reduction of side-lap fastener shear capacity due to uplift. The diaphragm stiffness is not affected by interaction. Stiffness can be obtained from the SDI Diaphragm Design Manual.

Output: This design aid output provides:

1. The allowable diaphragm shear in the absence of uplift pressure.
   This is the value commonly presented in the SDI Diaphragm Design Manual (DDMO3), which defaults to the three span case. SDI DDMO3 presents nominal values and not allowable values.
2. The allowable diaphragm shear in the presence of uplift pressure.
3. The safety factor used to determine the resultant allowable diaphragm shear.
4. The nominal (ultimate) diaphragm shear resistance in the presence of uplift pressure.
   The allowable equals this value divided by the safety factor.
5. The percent reduction in allowable diaphragm shear caused by uplift.
6. A check on the "stand alone" uplift resistance of the fastener group.
   If the word, "continue", appears next to the "ultimate uplift resistance with out shear," then the capacity is adequate.

Safety Factors: The design aid safety factors are input by the designer. The input page presents typical values to assist the designer but selection is not limited to these values. The input values are those in the *SDI Diaphragm Design Manual Third Edition,* Table 2.1, which presents acceptable safety factors (Ω for Allowable Strength Design) and resistance factors (Φ for Load Resistance Factor Design). These factors also are contained in Table D5 of the 2004 Supplement to the AISI *North American Specification for the Design of Cold-Formed Structural Members, 2001 Edition.* Some building codes require safety factors that differ from the design aid values. It is permissible to apply alternate factors to the nominal (ultimate) shear resistance however note the controlling limit state -- Does panel buckling control or do fasteners control? The appropriate factored resistance is then compared with

the design service diaphragm shear load (ASD) or the design factored diaphragm shear load (LRFD).

Input: This design aid input requires:

1. **Profile –** select roof deck type from the menu – output confirms the profile

2. **Thickness –** select gage from the menu – output confirms the design steel thickness

3. **Cover:** Select from the menu. Typically the greater cover widths are more efficient. There is less potential for slip along the side-lap seams. Split panels are to be avoided at shear walls for this reason. The preferred cover widths in inches are:

Type	Gage	Cover	
		Northeast	Midwest / Southeast
B, BI*	22 – 16	36	36
F	22-18	30**	36
N, NI	22-16	24	24

* 16 gage type BI is not readily available in the Northeast because it is not produced at our New Jersey plant. Type BI is not produced at our South Carolina plant.
** 36" preferred for 22 & 20 gage galvanized type F.

4. **Fastener Type:** This design aid considers the following in the draw down menus:
   Structural fasteners – welds, screws, proprietary power actuated fasteners
   Side-lap fasteners – welds, screws, button punching

   The typical fastener sub-set sizes are shown in the menu boxes and must be selected. The size most consistent with the type, e.g. .625 or .75 for welds. See the fastener limitations.

5. **Structural Attach Pattern:** There are several potential patterns at each cover width. The menu box contains these and the output sketch confirms the location of fasteners used in the calculations. The pattern must be consistent with the cover width. This design aid only considers the same fastener pattern at interior and exterior supports. The menu does not exhaust all possibilities. In extreme cases and with adequate support width to allow double rows, two welds are possible in each corrugation. The most effective structural fasteners are those furthest from the centerline of the sheet. When uplift is large, more structural fasteners will mitigate shear reductions.

6. **Uplift Pressure:** Do not input a negative sign. The uplift pressure is treated as the net uplift delivered to the deck. This is the unfactored pressure required by code and must be determined and input by the designer. The input is in psf.

7. **Yield Strength Selection:** This design aid considers differing grades of structural steel. All grades are available with sufficient lead-time but the steel grade must be clearly specified in the bid documents. We recommend that a yield strength (F_y) = 40 ksi be used in typical roof deck designs.

8. **Number of Spans Selection:** This design aid provides the ability to check single , double, or multiple spans. There is a slight variation in allowable diaphragm shear as the number of spans varies from 3 to 10. It is common practice to use the 3 span condition for quick design. An overall panel length of 30 to 40 feet is a practical limit. Job site conditions can require less.

9. **Safety Factor Selection:** See discussion above

Fastener Limitations: This design aid considers welds, screws, or classified (standard) power actuated fasteners at the supports. We recommend a maximum fastener spacing of 12" o.c. (more fasteners are acceptable). The exception is 30" coverage where a maximum spacing of 18" is acceptable to SDI. A fastener should always be placed at the side-lap. With certain restrictions, other support fasteners are acceptable to SDI. The primary category is non-standard power-actuated fasteners. We recommend that the alternate fastener manufacturer be contacted for results particular to their product. The same techniques used in this design aid are applicable to those products.

When interlocking side-laps are used, structural fasteners are required either side of the side-lap at the supports. If the side-lap has a sufficient horizontal return so that a common fastener sufficiently engages both deck edges, then only one fastener will be required at the side-lap.

This design aid considers welds, screws, or button punching at the side-laps. Button punching is only possible on interlocking type profiles. Screws are only possible at nestable type side-laps or at interlocking side-laps with a horizontal return on the female lip. The default maximum side-lap fastener spacing is 36" o.c. for spans greater than 5' 0". The design must consider this when inputting the number of side lap fasteners per span.

This design aid assumes that the support is sufficiently thick to allow welding. In the case of screws, this design aid assumes that the support is sufficiently thick that bearing of the deck against the screw controls the shear strength. If the thickness is such that tilting of the fastener reduces the shear strength, this design aid does not apply however the SDI method can be used to obtain a design value using the reduced shear strength of the screw.
See the discussion below for Power Actuated Fasteners concerning support thickness:

Manufacturer	Type	Thickness Limits
Buildex	BX12	.125” min
Buildex	BX14	.125” min
Hilti	ENP2	.25” min
Hilti	ENPH2	.25” min

Hilti	ENP2K	.125” min to .375” max
Hilti	X-EDN19	.125” min to .375” max
Hilti	X-EDNK22	.125” min to .375” max
Pneutek	SDK61	.113” min to .155” max
Pneutek	SDK63	.155” min to .25” max
Pneutek	K64	.187” min to .312” max
Pneutek	K66	.281” min

Welding

1. Weld washers are not recommended for thickness greater than or equal to .028 inch. This design aid only considers arc spot welds (puddle welds).
2. This design aid requires a minimum Electrode of E60XX.
3. We recommend a minimum visible arc spot weld diameter of 5/8 inch.
4. Welding must be performed in accordance with AWS D1.3.
5. Field quality control procedures are essential to obtain adequate welds.
6. The trend is towards screwed side-laps but welded side-laps are still an acceptable option.
7. SDI recognizes a 1 1/2" long fillet weld as being equal to a 5/8" arc spot weld at side-laps. A slot weld that has the same perimeter as a 5/8” arc spot weld is acceptable at supports.
8. Only choose ¾” diameter welds when substitution of more 5/8” diameter welds does not meet the project service requirements. The designer can have more confidence that 5/8” diameter welds will be made in the field.

Screws

1. This design aid considers No. 12 or No. 14 screws at supports. SDI assigns the same shear strength to either diameter screw when they are used at structural supports.
2. This design aid uses a screw washer diameter head of = 0.4" for No. 12 screws and = 0.41" for No. 14 screws. Other diameter heads and washers are available and these can affect the uplift capacity and the interaction. The assumed values are representative of hex washer head screws however hex heads can be closer to 0.34” for No. 12 screws. We recommend that the Engineer look at the percent reduction in allowable diaphragm shear. If this value is not large, then the design aid is sufficient for design analysis for most screws of known diameter. Presently the AISI specification limits the effective head diameter to .5”.

Power Actuated Fasteners

This design aid considers those proprietary fasteners that have been classified in the *SDI Diaphragm Design Manual Third Edition.* The method assumes the support is sufficiently thick that bearing of the deck against the pin is the controlling limit. SDI suggests a minimum thickness of 1/8”. Particular pins are applicable over a prescribed thickness range. See the table above at Fastener Limitations.

Button Punching

Button punching is commonly used on roof deck panels with interlocking side-laps. The Steel Deck Institute makes the following statement: “Button punched side-laps do stabilize

panel edges, but may contribute little to diaphragm strength." SDI further states, "A conservative approach for using the tables (for diaphragms) with button punched side-laps is to consider the button punches as having zero strength…"

This conservative method is used in this design aid. Shear values for any spacing of button punches will be the same as the shear value with zero side-lap screws or side-lap welds.

Acoustic Decking

Acoustic deck has holes punched in the webs. These holes have little impact on panel flexural stiffness. Since diaphragm strength is primarily dependent on fastener strength and the fasteners are through solid (non perforated) flanges, the same diaphragm values apply to acoustic and standard deck with everything else being equal.

Additional Information: If this tutorial does not address a particular issue, contact the South Plainfield, NJ office for additional information.

Phone: 908-561-3484
Email: michael.martignetti@canam.ws

return to cover