



# **HOW TO UPDATE DIAPHRAGM TABLES**

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## How to use the existing Diaphragm Tables for LRFD

The Steel Deck Institute *Diaphragm Design Manual, Second Edition (1987)* contains ASD (Allowable Stress Design) load tables for diaphragm design. The tables are presented in an ASD format although their development followed the LRFD (Load Resistance Factor Design) approach. The Steel Deck Institute *Diaphragm Design Manual, First Edition (1981)* is actually composed of two books put into one volume. The second part is titled "Steel Deck Diaphragm Studies" and presents a very complete report of the testing and a thorough development of the reliability factors and margins of safety. Fastener studies are included because diaphragm performance is very sensitive to the method and frequency of fastening. The tables that appear in the second edition are based on the  $\phi$  and  $\psi$  factors developed for the first edition. Subsequent research and testing done on diaphragms since the publication of the first edition confirmed the validity of the earlier testing and analysis. The tables published in the second edition can still be used with newly adjusted resistance and safety factors; the purpose of this paper is to demonstrate the method. The original form of the evaluation was:

$$\phi R \geq \psi_o(\psi_L + \psi_D + \psi_E + \psi_W)W$$

where:

R = nominal resistance or strength

$\phi$  = probable understrength factor

$\psi$  = overload factors as indicated for loading conditions

L = live load or live load subscript

D = dead load or deal load subscript

E = earthquake loading

W = nominal wind loading

The ASD diaphragm tables were developed in the SDI Diaphragm Design Manual, 1<sup>st</sup> Edition, as:

$$\phi R \geq \psi_o(\psi_W)W$$

where  $\psi_o$  was a load combination factor. With combinations of the  $\psi$ -terms, the above equation may be extended to a working load form for diaphragms:

$$\phi S_N = \psi S_A \text{ or } S_A = S_N / (\psi / \phi)$$

with the N and A subscripts representing nominal shear strength and allowable shears respectively.

The  $\psi/\phi$  term may be thought of as a "safety factor" which, for the SDI tables, was: 2.35 for screw connected diaphragms, 2.75 for welded diaphragms, and 3.25 for diaphragms with concrete fills.

The SDI  $\phi$ -factors were developed as a part of the SDI research program and using the  $\psi$ -factors of the time. These factors allow the direct determination of the nominal ultimate strength of a diaphragm. Simply multiply the SDI listed allowable shear by the safety factor shown at the top of the page to find  $S_N$ .

Both the  $\phi$ - and  $\psi$ -factors have undergone modest changes since the SDI safety factors first were developed. It is expected then that "allowable" diaphragm shears would also change as code committees introduce newer factors.

As an example, consider a **screw connected** diaphragm with an ASD shear of 100 lbs/ft. as shown in the tables of the 2<sup>nd</sup> Edition of the Diaphragm Design Manual. The SDI safety factor is 2.35 then the nominal shear strength is  $S_N = 2.35 (100) = 235$  lbs/ft. The current AISI  $\phi$ -factors and load factors are as on the attached pages. Here  $\phi = 0.65$  and the wind load factor,  $\psi = 1.3$ . These values are the equivalent of setting:

$$1.3 W = 0.65 S_N = 0.65(235) = 152.8 \text{ or } W = 118 \text{ lbs/ft.}$$

With  $W$  the same as the allowable or working values, it is obvious that the new "working" formulations show an eighteen percent increase. Increases are expected since the current 1.3 wind factor is smaller than that originally used.

If a wind-loaded diaphragm, connected by welding, shows an ASD shear of 100 lbs/ft. from a 2<sup>nd</sup> Edition SDI table, then the safety factor is 2.75 and the nominal strength is  $S_N = 2.75(100) = 275$  lbs/ft. The current  $\phi$ -factor is 0.55. If one were to combine these for a current ASD load, the new value would be:

$$W \text{ or } S_A = 0.55(275) / 1.3 = 116 \text{ lbs/ft.}$$

For earthquake conditions,  $\phi = 0.50$ ,  $\psi = 1.5$ , and  $S_A$  would equal  $0.50(275) / 1.5 = 92$  lbs/ft.

In limit state design, all these maneuvers are not necessary. The only necessity is to keep  $\phi S_N$ , the system resistance, greater than the shear developed from the factored loads.

The AISI A6.1.2 Load Factors and Combinations, attached, contain a Footnote 1 relating to Combinations 5 and 6. These two entries contain a 1.5 factor for E-loads, with E-loads apparently set as "working loads." If the seismic model already contains the load factors in its E-loads, the 1.5 value simply is replaced by unity to avoid doubling-up on the factor.

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Section A6.1.2 and table D5 are copied directly from the American Iron and Steel Institute (AISI) 1996 Cold-Formed Specification.

### **A6.1.2 Load Factors and Load Combinations\***

In the absence of an applicable code or specification or if the applicable code or specification does not include LRFD load combinations and load factors, the structure and its components shall be designed so that design strengths equal or exceed the effects of the factored nominal loads for each of the following combinations.

1.  $1.4D + L$
2.  $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R_p)$
3.  $1.2D + 1.6(L_r \text{ or } S \text{ or } R_p) + (0.5L \text{ or } 0.8W)$
4.  $1.2D + 1.3W + 0.5L + 0.5(L_r \text{ or } S \text{ or } R_p)$
5.  $1.2D + 1.5E + 0.5L + 0.2S$
6.  $0.9D - (1.3W \text{ or } 1.5E)$

Exceptions:

1. The load factor for E in combinations (5) and (6) shall equal 1.0 when the seismic load model specified by the applicable code or specification is limit state based.
2. The load factor for L in combinations (3), (4), and (5) shall be equal to 1.0 for garages, areas occupied as places of public assembly, and all areas where the live load is greater than 100 psf.
3. For wind load on individual purlins, girts, wall panels and roof decks, multiply the load factor for W by 0.9.
4. The load factor for  $L_r$  in combination (3) shall equal 1.4 in lieu of 1.6 when the roof live load is due to the presence of workmen and materials during repair operations.

**TABLE D5**  
**Factors of Safety and Resistance Factors for Diaphragms**

$\Omega_d$	$\phi_d$	Diaphragm Condition
2.65	0.60	for diaphragms for which the failure mode is that of buckling, otherwise;
3.0	0.50	for diaphragms welded to the structure subjected to wind load subjected to load combinations which include earthquake loads.
2.35	0.55	for diaphragms welded to the structure subjected to wind loads, or subjected to load combinations which include win loads.
2.5	0.60	for diaphragms mechanically connected to the structure subjected to earthquake loads, or subjected to load combinations which include earthquake loads.
2.0	0.65	for diaphragms mechanically connected to the structure subjected to wind loads, or subjected to load combinations which include wind loads
2.45	0.65	for diaphragms connected to the structure by either mechanical fastening or welding subjected to load combinations not involving wind or earthquake loads.