USD United Steel Deck, Inc.

Composite Floor Deck Slabs

General Information

After installation and adequate fastening, composite steel decks (floor decks) serve several purposes. They act as working platforms, stabilize the frame, serve as concrete forms for slabs, and provide positive bending reinforcement. All USD composite decks are made to mechanically interlock with the concrete by the use of "rolled in" embossments.

Construction

Deck should be selected to provide a working platform capacity of at least 50 psf. If temporary shoring is required to obtain this capacity, it should be available to support the deck as the deck is being installed. Generally, deck is selected to perform without the use of temporary shores; maximum unshored spans are shown in the tables. As the deck is being erected, it is important to immediately attach it to the structural frame so a working platform is made. All OSHA rules for erection must be followed. The SDI Manual of Construction with Steel Deck is a recommended reference.

When placing concrete, care must be taken to avoid high pile ups of concrete and to avoid impacts caused by dropping or dumping. If buggies are used, runways should be planked and deck damage caused by roll bars or careless placement practices should not be allowed.

Finishes

Composite deck is available galvanized (G30, G60 or G90) and "phosphatized/painted". When the deck is furnished "phosphatized/ painted", only the side not in contact with the concrete is painted so chemical bond between steel and concrete can occur. ("Phosphatizing" is a cleaning process.)

Wire Mesh

Temperature reinforcing should be present in composite slabs. The wire mesh recommendations shown in the tables follow the SDI recommendation for a steel area of 0.00075 times the area of concrete above the deck flutes. The mesh shown in the tables is not proportioned to act as negative reinforcement but it does add some strength to the system. **If welded wire fabric is not used, the loads in the tables should be reduced by 10%.** For best crack control, mesh should be kept near the top of the slab in negative bending regions (3/4" to 1" cover). Mesh also helps to distribute loads, both during construction and during the service life of the slab. It can also be a secondary safety device if there is a collapse during concrete placement.

Parking Garages

Composite floor deck is not recommended for parking garages in the northern part of the United States; salt brought because of snow removal can deteriorate the deck. Deck can be used as a permanent form and reinforcing (mesh or bars) should be used.

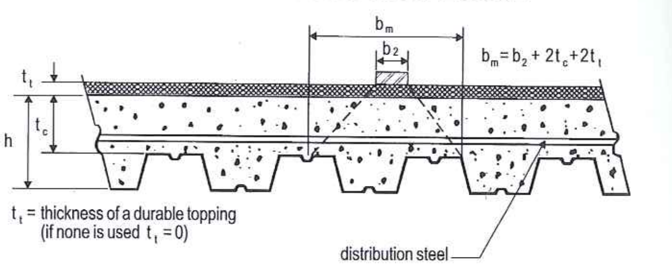
The Tables

The tables are arranged so the composite properties are on the left page. The uniform live load capacities are shown on the right page. Tables are provided for both light weight and normal weight concrete; both types assume a concrete strength of 3000 psi. The tables are based on a steel yield strength of 33 ksi; however, 40 ksi minimum yield steel is also readily available and tables based on this strength are available upon request. Maximum unshored spans are shown on the left page. These spans may be taken as clear spans and SDI Construction loading is used to determine the values. The tabulated variables are defined on each page.

The research done on composite deck has shown that the presence of shear studs influences the live load of the system. When a sufficient number of shear studs are present, the composite slab can achieve its predicted ultimate strength. When no shear studs are present the factored moment is found by $M_{no} = \phi S_c F_y$, where ϕ is 0.85 and S_c is the cracked composite section modulus of the composite slab. If the number of studs present is between the amount required to produce the "fully" studded moment and zero, then a straight line interpolation is valid. Generally, the load capacity of composite slabs is greater than required by the intended use, and the number of studs is not of importance. Studs are used primarily to make beams composite and the composite slab simply uses what is there - the average number of studs (per foot) can be used. The right page tables are therefore divided into two parts. Those with one stud per foot and those with no studs.

Both tables assume that no negative bending reinforcement is in place and the composite deck has been analyzed as a single span. An upper load limit of 400 psf has been applied. This is to guard against uniform loads being equated from heavy concentrated loads which require more analysis. Uniform loads greater than 400 psf can be analyzed by using the data provided. Concentrated loads can be designed as shown in the following example problem. The loads have been determined by solving the equation for W_l (the live load): $1000 \times M = [1.6 W_l + 1.2 W_c] L^2 (12)/8$ where M is the appropriate listed factored moment, either M_{nf} or M_{no}; W_c is the sum of the concrete and deck weight; L is the span in feet. Although other load combinations may be investigated, $1.6 W_l + 1.2 W_c$ usually controls.

Distribution of Concentrated Loads



The load width (above the ribs) is given by:

$$b_m = b_2 + 2t_c + 2t_t$$

The effective slab width (b_e) formulas are:

single span bending: $b_e = b_m + 2(1 - x/l)x$;

Single span bending distribution is to be used if negative bending reinforcing steel is not placed over the supports.

continuous span bending: $b_e = b_m + 4/3\,(1 - x/l)x$

Continuous span bending is to be used if negative bending reinforcing steel is present over the supports.

For shear (single span or continuous) $b_e = b_m + (1 - x/l)x$.

But, in no case shall $b_e > 8.9(t_c/h)$, feet.

The **Weak Axis Moment** (for distribution steel); $M(\text{weak axis}) = \frac{Pb_e}{15w}$, where w is the distribution parallel to the ribs:

$$w = l/2 + b_3; \text{ but not to exceed } l$$

l = span length; **x** = location of the load measured from the support; **b_2** = load width perpendicular to the flutes; **b_3** = load width parallel to the flutes.

Suggested Floor Deck Specifications

1. Material and Design

1. Composite floor deck shall be type_____ as manufactured by United Steel Deck, Inc. from steel conforming to ASTM A611 or ASTM A653 with a minimum yield point (F_y) of 33 ksi.
2. Floor deck shall extend over three or more spans if possible. [The depth and gage of floor deck shall be selected to not exceed the unshored spans as calculated by using LRFD methods under the construction loadings recommended by SDI.]* Deflection caused by the dead load of wet concrete and deck shall not exceed L/180 for any span or 3/4".
3. Live load capacities shall be calculated in accordance with the SDI Composite Deck Design Handbook. The type and gage of the metal floor deck shall be selected to carry, by acting compositely with the concrete, the superimposed live loads shown on the project drawings without exceeding a deflection of 1/360 of the span.

2. Finishes

1. Galvanizing shall conform to the requirements of ASTM A653 coating class G30, G60 or G90 or Federal Specification QQ-S-775e, class d or class e.

or

2. Primer paint shall be shop applied over cleaned and phosphatized steel - paint applied only on the exposed side of the deck. The side of the deck that is to be in contact with the concrete is to be uncoated or galvanized.

3. Installation

1. Installation of floor deck and accessories shall be done in accordance with the SDI Manual of Construction with Steel Deck and as shown on the detailed erection drawings. Welds to supports should be 5/8" diameter puddle welds with an average weld spacing of at least 12" on center. Side laps are to be welded at a maximum spacing of 36" on center. (Fasteners other than welds may be acceptable to United Steel Deck, Inc.)
2. Floor openings located and detailed on the structural drawings shall be cut by the floor deck contractor. Holes for other trades plus any reinforcing for these holes shall be cut and reinforced by the other trades.

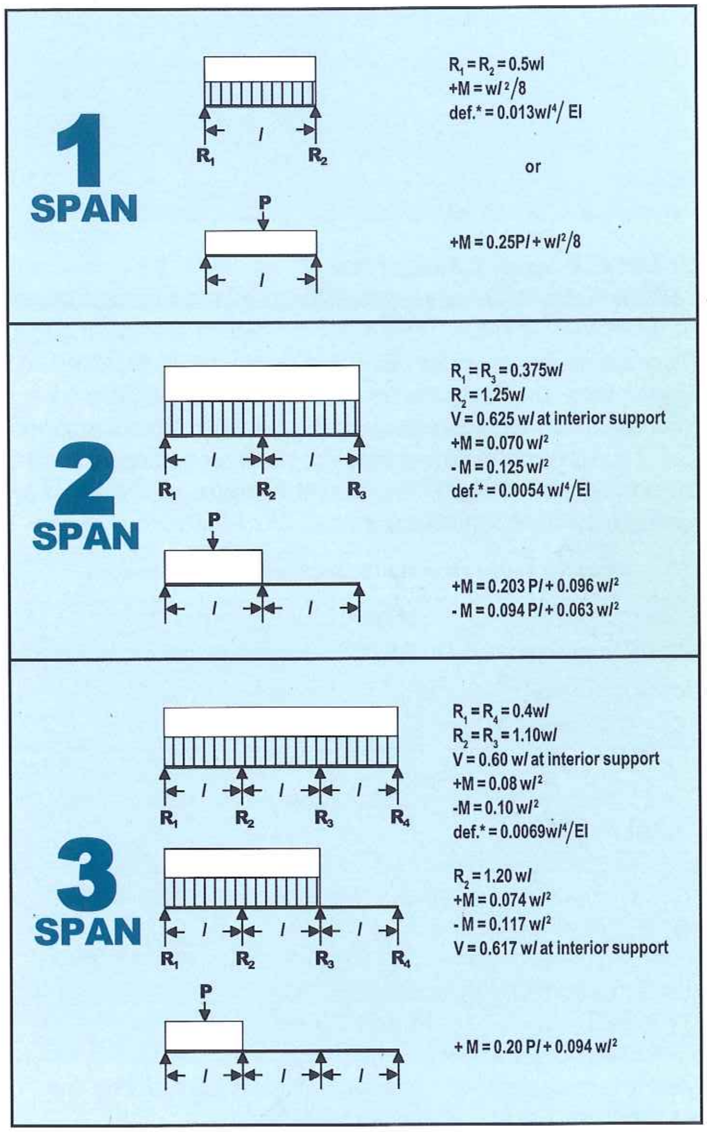
4. Concrete

1. Placement of concrete shall conform to the applicable sections of the ACI Specifications. If buggies are used, the deck shall be planked to prevent damage.
2. Calcium Chloride: Calcium Chloride (or any admixture containing chloride salts) shall not be used in concrete placed on products manufactured by United Steel Deck, Inc.

* Eliminate this clause if shoring is allowed.

SDI Formulas for Construction Loads

Clear spans may be used in the formulas.
For checking web crippling (bearing) the uniform loading case of concrete weight plus 20 psf is used - ASD is used.



For single spans only, the concrete load shall include either an additional 50% of the concrete weight or 30 psf whichever is less.

* Deflection is to be calculated using only concrete plus deck weights uniformly distributed over all spans.

Key

- uniform concrete load
- uniform construction load (20 psf, unfactored)
- P — concentrated man or equipment load (150 lbs./ft. of width unfactored)
- *l* — clear span

Example Problem (COMPOSITE FLOOR DECK)

THIS EXAMPLE PROBLEM USES 20 GAGE (t = 0.0358") 2" LOK FLOOR COMPOSITE DECK MADE FROM STEEL WITH A 33 ksi (MINIMUM) YIELD POINT. THE DECK PROPERTIES (PER FOOT OF WIDTH) HAVE BEEN CALCULATED IN ACCORDANCE WITH THE AMERICAN IRON AND STEEL INSTITUTE (AISI) SPECIFICATIONS AND ARE: $I = 0.420$ in.^{4}, $S_p = 0.367$ in.^{3}, (SECTION MODULUS IN POSITIVE BENDING); $S_n = 0.387$ in.^{3}, (SECTION MODULUS IN NEGATIVE BENDING); $A_s = 0.54$ in.^{2}; $R_b = 1010$ lbs.; $\phi V_n = 2410$ lbs.; w = 1.8 psf. R_b IS THE ASD INTERIOR WEB CRIPPLING CAPACITY BASED ON A 5" BEARING AND ϕ V IS THE FACTORED DECK SHEAR STRENGTH. SDI TOLERANCES APPLY. THE CONCRETE PROPERTIES ARE: $f'_c = 3$ ksi; DENSITY = 145 pcf. THE RATIO OF THE MODULI, $n = E_s/E_c = 9$.

Unshored Span Calculation

Calculate the maximum unshored clear span for the three span condition of the deck with a 4.5" slab.
The resistance factors and the load factors are provided by the AISI Specifications. The load factors are 1.6 for concrete weight, 1.4 for construction loading of men and equipment, and 1.2 for the deck dead load. It is important to remember that these factors are for the deck under the concrete placement loads; when the slab has cured, and the system is composite, the factors are different.

REFER TO PAGE 17 FOR FIGURE SHOWING 3 SPAN CONDITION.

$w_1 = w_{concrete} = 42$ psf.; $w_{deck} = 1.8$ psf.
Web crippling, shear, and the interaction of bending and web crippling are checked with two spans loaded.

Check negative bending with two spans loaded:
$-M = 0.117l^2(1.6x42 + 1.4x20 + 1.2x1.8) = 0.95(33000)(0.387)/12;\ l = 9.42'$
Check positive bending with one span loaded with concrete and the concentrated load:
$+M = 0.20(1.4x150)l + 0.094l^2(1.6x42 + 1.2x1.8) = 0.95(33000)(0.367)/12;\ l = 9.33'$
Web crippling, shear, and the interaction of bending and web crippling are checked with two spans loaded.
Check interior web crippling (note 1/3 stress increase allowed for ASD temporary loading for web crippling):
$R_i = 1.20(42 + 20 + 1.8)\ l = (1010 \times 1.33);\ l = 17.55'$
$\phi V = 0.617(1.6 \times 42 + 1.4 \times 20 + 1.2 \times 1.8)l = 2410;\ l = 40.12'$
Shear or bending alone will not control, but the interaction of shear and bending could. The AISI equation for interaction is:
$(M_{applied} / \phi M_n)^2 + (V_{applied} / \phi V_n)^2 \leq 1.0$
$M_{applied} = 0.117l^2(1.6 \times 42 + 1.4 \times 20 + 1.2 \times 1.8)12 = 136.7l^2$ inch lbs.
$\phi M_n = 0.95\ (33000)(.387) = 12132$
$V_{applied} = (1.6 \times 42 + 1.4 \times 20 + 1.2 \times 1.8)0.617l = 60.07l$
$(136.7l^2/12132)^2 + (60.07l/2410)^2 = 1.0$
Solving for *l* yields *l* = 9.29'
Check deflection with $y = l/180$ and with y = 0.75" limits;
$y = l(12)/180 = 0.0069(42 + 1.8)l^4(1728)/(29.5 \times 10^6 \times 0.420);\ l = 11.64'$
$y = 0.75 = 0.0069(42 + 1.8)l^4(1728)/(29.5 \times 10^6 \times 0.420);\ l = 11.55'$

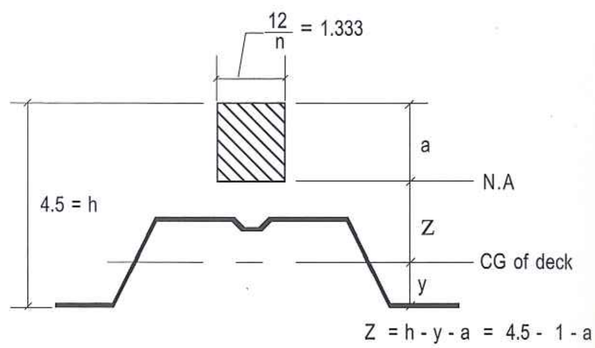
Combined bending shear governs, tables show maximum unshored span of 9.27.

Composite section properties

Calculate the composite section properties and the allowable uniform load for the deck slab combination. The clear span is 9'. No negative bending reinforcing is used over the beams, so the composite slab will be a simple span.

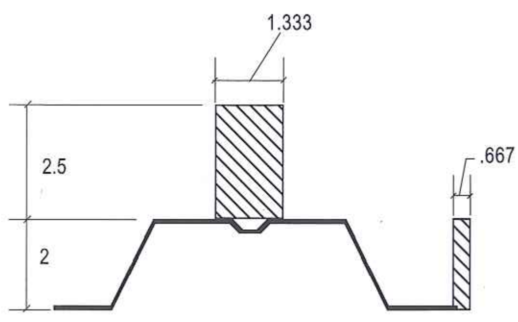
$n = E_s/E_c = 9$; $A_s = 0.54$ in.^{2}; $I = 0.42$; A_s and I are per foot of width.

Determine the "cracked" I. This calculation is the standard ASD calculation which assumes all concrete below the neutral axis is cracked. The concrete is transformed into equivalent steel.



Moments (of areas) about the neutral axis (N.A.) are summed in order to locate the N.A.
$(12/n)a(a/2) - A_sZ = 0$: $1.333a^2/2 - 0.54(3.5 - a) = 0$
Solving for a shows a = 1.33"; 1.33 < 2.5 O.K.; Z = 2.173
$I_c = 1.333(1.33)^3/3 + 0.54(2.173)^2 + 0.42 = 4.02$ in.^{4}
The cracked section modulus = $I_c/(h - y_c) = 4.02/(4.5 - 1.33) = S_c = 1.27$ in.^{3}. The table printout shows 1.26, which checks.

Determine the "uncracked" moment of inertia (I_{uc}). The concrete is again transformed into equivalent steel.



Using the top of the slab as the reference line:
$$y_{uc} = \frac{\Sigma Ay}{\Sigma A} = \frac{1.333(2.5)^2/2 + 0.667(2)(2.5 + 2/2) + 0.54(2.5 + 2 - 1)}{2.5(1.333) + 0.54 + 0.667(2)} = 2.06 \text{ in.}$$
and the uncracked I is:
$I_{uc} = 1.33(2.5)^3/12 + 1.333(2.5)(2.06 - 2.5/2)^2 + 0.42 + 0.54(4.5 - 2.06 - 1)^2 + 0.667(2)^3/12 + 0.667\ (2)\ (4.5 - 2/2 - 2.06)^2 = 8.67$ in.^{4}
$I_{av} = (I_c + I_{uc})/2 = (4.02 + 8.67)/2 = 6.3$ in.^{4}

Calculate the unfactored (allowable) live load for the case with no studs. The clear span is 9'.

The factored moment is; $\phi M_0 = \phi F_y S_c$, where S_c is the section modulus of the cracked section as previously determined, and the ϕ factor is 0.85.

$\phi M_0 = 0.85(33000)1.26 = 35343$ inch pounds = 35.34 inch kips. The printout shows 35.43 which checks within 1%.

Unless negative bending reinforcement is present, the composite slab is assumed to be single span. For a single span, the unfactored uniform (live) load (w_l) is found by:

$\phi M_0 = (1.6w_l + 1.2\, w_d)l^2(12)/8 = 35343$; w_d = dead load = 42 + 1.8 = 43.8 use 44; l = 9'.

Solving for w_l shows w_l = 150 psf rounded to the nearest 5 psf.

Check the deflection if the applied load is 150 psf.

With no negative reinforcing, the composite slab is a single span.

$\Delta = 0.013\, w_l l^4/ EI_{av} = 0.013(150)9^4(1728)/ (29.5 \times 10^6 \times 6.3) = 0.12"$ which is $l/900$ and should be O.K.

Check the factored vertical shear capacity:

$\phi V_{steel\,deck}$ = 2410 pounds (per foot of width).

$\phi V_{concrete} = 0.85(2)(f'_c)^{½}A_c = 0.85(2)(3000)^{½}(32.6) = 3035$ pounds = 3040 use

ϕV_{nt} = 2410 + 3040 = 5450 pounds.

Check the concrete shear control limit: $0.85(4)(f'_c)^{0.5}A_c = 2(3040) = 6080$ lbs. 5450 < 6080 pounds. (The tabulated value is 5450 - checks)

The unfactored (allowable) live load if shear controls (w_v) is found by: $5450 = (1.6w_v + 1.2 \times 44)(9)/2$; w_v = 724 psf. So obviously shear does not control the live load.

The number of studs required to develop 100% of the factored moment is given by:

$N_s = F_y(A_s - A_{webs}/2 - A_{bot.flange}) / [0.221(f'_cE_c)^{0.5}]$; the numerator of this equation is specific to the deck being used and the denominator is AISC equation I5-1. For this 20 gage 2" x 12" deck

$N_s = 33 \times 7.7 \times 0.0358/21.92 = 0.42$ studs per foot (The printout shows 0.43 because of round off.)

The inverse 1.0/0.43 = 2.33 which means a stud is required every 2.33' in order to achieve the full factored moment.

The full factored moment is $\phi M_n = 0.85F_yA_s(d\text{-}a/2)$. In this equation a is the depth of the concrete compression block and is given by

$a = A_sF_y/(0.85\, f'_cb)$ where b is 12".

$a = 0.54(33000)/(0.85 \times 3000 \times 12) = 0.58"$; d is measured from the top of the slab to the centroid of the deck and is 3.5".

$\phi M_n = 0.85(33000)0.54(3.5 - 0.58/ 2) = 48622$ inch pounds. The printout shows 48.60 inch kips, which checks.

Since N_s = 0.43 and $1/N_s$ = 2.33', studs spaced at 1' and 2' will develop the full factored moment of 48.60 inch kips, and with no studs the composite slab develops 35.43 inch kips. If studs are spaced at 3' (1/3 =0.33 studs per foot) then the composite slab capacity is found by interpolation:

$\phi M_n = 35.43 + (48.60 - 35.43)0.33/0.43 = 45.54$ inch kips.

Concentrated Load

Check the ability of the example composite slab to carry a 2000 pound concentrated load over an area of 4.5" x 4.5"; the load can occur at any location in the span. No other live load will be acting at the same time. Assume that there is no negative bending reinforcing steel in the slab over the supports even though there will be wire mesh. The wire mesh usually is not sufficient to supply the total negative bending needs; in this problem we will also determine the wire mesh required to act as distribution steel. If moving loads can cross into adjacent spans, such as a fork lift truck, negative bending reinforcement is recommended.

Since there is no negative steel, the composite slab is considered to be simple span.

clear span = l = 9' = 108"; $b_2 = b_3 = 4.5"$; $b_m = b_2 + 2t_c + 2t_t$; where t_c is the concrete cover over the top of the deck , and t_t is the thickness of any topping; h is the total thickness exclusive of the topping. In this case, h = 4.5", t_c = 2.5" and t_t = 0".

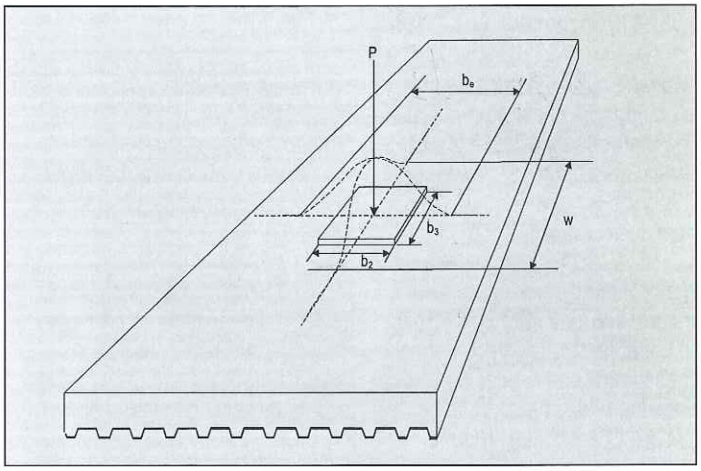
$b_m = 4.5 + 2(2.5) + 0 = 9.5"$

For moment, and for determining the distribution steel, put the load in the center of the span.

$b_e = b_m + 2(1 - x/l)x$; where x is the location of the load which is $l/2$.

$b_e = 9.5 + 2(1 - 54/108)54 = 63.5"$; but b_e is not to exceed $8.9(t_c/h)$ in feet.

$8.9(2.5/4.5)(12) = 59"$; $b_e = 59"$.



For checking vertical shear, put the load one slab depth away from the beam, x = h:

$b_{ve} = b_m + (1 - h/l)x = 9.5 + (1 - 4.5/108)(4.5) = 13.8"$. 13.8 < 59, so for Moment use b_e = 59" and for shear b_{ve} = 13.8".

Live load moment (per foot of width) = $Pl/4 = (1.6)2000(9/4)(12/59)12/1000 = 17.57$ inch kips. Where 1.6 is the load factor and (12/59) is the distribution factor.

w_d = total dead load = 42 + 1.8 = 43.8 use 44 psf.

Dead load moment = $w_dl^2/8 = 1.2(44)9^2(12)/8000 = 6.42$ inch kips.

17.57 + 6.42 = 23.99 inch kips.

ϕM_{no} ,the factored resisting moment without studs, is = 35.34 inch kips; 35.34 > 23.99 O.K. (continued on next page)

LRFD

(continued from page19)

$V = 1.6(2000)(12/13.8) + 1.2(44)9/2 =$ 3020 lbs. $\phi V_{nt} = 5450$ lbs.; 5450 > 3020 O.K.

Find the required distribution steel (welded wire mesh):

M_2 = weak direction moment = $Pb_e/(15W)$;

$W = l/2 + b_3 = 54 + 4.5 = 58.5" < 108"$

$M_2 = 1.6(2000)(59)(12)/(15 \times 58.5) = 2582$ inch pounds (per ft.)

Assume that the wire mesh is located 1/2" above the top deck surface so that d = 2". (In the positive moment region)

$M_r = 0.85A_sF_y(2-a/2)$; In this equation A_s is the area (per ft.) of the wire mesh which has an F_y of 60 ksi. If bars are being investigated, the F_y would have to be adjusted accordingly. (Note that ϕ is 0.9 in the ACI but is 0.85 in the SDI method.)

$a = A_sF_y/(0.85f'_cb)$, where b is 12"; assume A_s is the area of 6 x 6 W1.4 x 1.4 mesh, which is the least allowed by SDI. $A_s = 0.028$ in.^{2} (per ft.).

$a = 0.028(60000)/(0.85 \times 3000 \times 12) = 0.055"$

$\phi M_{weak} = 0.85(0.028)(60000)(2 - .055/2) = 2816$ inch lbs per foot of width.

2816 > 2582 O.K. The SDI minimum welded wire mesh is sufficient.

Check the deflection under the concentrated load:

$I_{av} = 6.3$ in.^{4}/ ft. of width.

Put the load in the center of the span, and, for simplicity, use concentrated load coefficients.

$y = Pl^3/(48EI)$; P (per foot) = 2000(12)/59 = 407 lbs.

$y = 407(9)^3(1728)/(48 \times 29.5 \times 10^6 \times 6.3) = 0.06"$

0.06" is approximately $l/1800$, this should be O.K.

All model building codes require, for some building classifications, the slab to be capable of carrying a 1000 or 2000 lb. load over a 30" x 30" area. The methods shown in this example problem can be used for that particular loading - the footprint of the load would, of course, be larger. This code requirement will probably never be the controlling factor for a steel deck composite slab.

In most cases building codes or other reference literature will call for a uniform live load. For instance the 1996 BOCA code calls for offices to be capable of carrying 50 psf, lobbies 100 psf, and corridors 80 psf. These loads can be looked up directly in the Lok-Floor and B-Lok tables since the tables have printed L, the live load, by solving the equation $\phi M_n = (1.6L + 1.2D)\, l^2/8$ for L.

The dead load, D, is taken as the slab and deck weight as shown in the example problem. Although it is possible that some load combination other than 1.6L + 1.2D may control, in most cases this combination is critical. For any combination of loading, the ϕ M values can be used to calculate the limits.

N-LOK

N Lok is a special version of composite deck. It was originally conceived as a second use for the N tooling used to make 3" deep roof deck. Unfortunately the rib dimension of the deck is narrow and the w/h ratio is too low to use it efficiently with shear studs for composite beams. The N Lok properties table is therefore shown for the "no stud" case only. N Lok is particulary useful in applications that use the product as roof deck with the intention of later ripping off the roof and pouring a floor.

N-LOK Example Problem

20 gage N Lok is to be used on a 10' clear span (3 span condition) with a 5.5" slab of normal weight concrete. Assume no negative bending reinforcing steel is used. Determine the live load.

From the tables: Maximum Unshored Span = 11.20' > 10' O.K.

$\phi M_{no} = 40.18$ in.k.

$I_{av} = 8.0$ in^4

$\phi V_{nt} = 3930$ lbs. (note this is less than the deck capacity alone, the ultimate shear strength of the concrete controls).

$\phi V_n = 5020$ lbs. (deck alone)

Check bending:

$w_d = 40 + 2.4 = 42.4$ use 43 psf

$40.18 \times 1000 = (1.6w_l + 1.2 \times 43)10^2(12)/8$

$w_l = 135$ psf

Check shear:

$V = 5020 = (1.6w_l + 1.2 \times 43)10/2$

$w_l = 595$ psf

Check deflection with def. $= l/360 = \frac{10(12)}{360} = 0.33"$

$0.33 = 0.013\, w_l(10)^4\, 1728/(29.5 \times 10^6 \times 8.0)$

$w_l = 347$ psf

Bending controls. The allowable live load is 135 psf.

The **Composite Properties** are a list of values for the composite slab. The **slab depth** is the distance from the bottom of the steel deck to the top of the slab in inches as shown on the sketch. U.L. ratings generally refer to the cover over the top of the deck so it is important to be aware of the difference in names. $\mathbf{A_c}$ is the area of concrete available to resist shear, in.^{2} per foot of width. **W** is the concrete weight in pounds per ft.^{2}. $\mathbf{S_c}$ is the section modulus of the "cracked" concrete composite slab; in.^{3} per foot of width. $\mathbf{I_{av}}$ is the average of the "cracked" and "uncracked" moments of inertia of the transformed composite slab; in.^{4} per foot of width. The $\mathbf{I_{av}}$ transformed section analysis is based on steel; therefore, to calculate deflections the appropriate modulus of elasticity to use is 29.5 x 10^6 psi. $\phi \mathbf{M_{no}}$ is the factored resisting moment of the composite slab with no studs on the beams (the deck is attached to the beams or walls on which it is resting) inch kips per foot of width. $\phi \mathbf{V_{nt}}$ is the factored vertical shear resistance of the composite system; it is the sum of the shear resistances of the steel deck and the concrete but is not allowed to exceed $\phi 4(f'_c)^{1/2} A_c$; pounds (per foot of width). The next three columns list the **maximum unshored spans** in feet; these values are obtained by using the construction loading requirements of the SDI; combined bending and shear, deflection, and interior reactions are considered in calculating these values.