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DESIGN EXAMPLE ON COMPOSITE STEEL DECK FLOOR SLABS

by

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The enclosed example is presented to demonstrate the intent and use of the AISI "Tentative Recommendations For The Design of Composite Steel Deck Slabs," and hereafter will be referred to as the criteria. Calculations utilizing procedures prior to the criteria are presented at the end of the example.

The first page in the Appendix states the given data namely: spans, loads, and fire rating. The fire rating dictates the minimum depth of concrete as per Underwriters Laboratories recommendations. The span and concrete dictate the steel deck size and thickness necessary to carry the wet concrete and construction loads. Selection of the deck falls into the same procedure as most design problems; "experience", whether it be yours or that of a steel deck supplier. The deck is assumed to span three 10 ft. spans.

Below the given data, the section properties for the deck selected are given. These properties were calculated in accordance with the "Specification For The Design of Cold Formed Steel Structural Members" 1968 Edition of the American Iron and Steel Institute. The composite properties of the steel deck and concrete are also given. They were calculated with cracked section theory using the full steel area of the deck. S+ designates the top of the deck in compression and S-

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means the bottom of the deck is in compression. The AISI properties given assumed a minimum yield strength of 33 ksi, with a base steel thickness of 0.042 inches.

The last two properties given are "m" the slope, and "k" the y intercept of the straight line developed from laboratory tests conducted in accordance with Chapter 3 of the criteria.

The first four steps calculate the dead load and the maximum deflection of the steel deck as a form. The maximum deflection cannot exceed 3/4 inch or $\ell/180$ whichever is smaller; 2.1.2.3 of the criteria. The ponding factor and deflection due to the wet concrete are based upon the formulae described in the A.I.S.C. Engineering Journal, April 1965, by J. Chinn. Any rational method may be used. The criteria states, "Additional concrete dead load due to deflection of the deck shall be considered in calculations."

The next five steps calculate the positive moments due to dead load and the construction loads specified in the criteria namely: 20 PSF uniform load or 150 lb. concentrated load on one foot of deck width. The uniform load moment coefficients assumed in the calculations are taken from the A.C.I. Standard 318-71, Part 4. The concentrated load moment coefficients are for the load in the center of the first span. The next two steps check the actual fibre stress in the deck for the moments calculated. The criteria states that the stresses shall not exceed those permitted in the AISI specification for the design of cold formed steel.

The next nine steps repeat the preceding procedure to check the deck stresses at the support, only using the applicable moment coefficients and S-.

The next calculation determines the allowable load per web of the deck using 3.5(a)(2) of the AISI Specification. The subsequent three steps calculate the maximum actual load per web due to dead and construction loads. This completes the check of the steel deck as a form to carry the construction loads and the wet concrete.

The next phase is to determine the allowable load on the composite slab. Since adequate reinforcement to allow the composite slab to act as a continuous beam is not present; the slab is considered as simple spans of ten feet. The ultimate shear in Lb./Ft. is determined using formula (7) of the criteria for shear-bond capacity. The allowable live load is then obtained using the load factors of 1.7 for live load and 1.4 for dead load. The live load becomes 104 PSF with 28 PSF dead load applied to the slab. The next step checks the allowable live load for a deflection of $\ell/360$ and is 338.5 PSF. The criteria states that the moment of inertia used shall be the average of the full composite inertia and the inertia obtained from cracked section theory. If the neutral axis falls within the deck, only the concrete above the deck is considered.

The criteria states that shrinkage reinforcement shall be provided equal to 0.001 of the area of concrete above the steel deck. This amounts to 6 x 6, No. 8 wire. This completes the design example per the criteria.

The last calculations show the allowable live load on the slab using the composite section properties cracked theory. The allowable steel stress is determined by deducting the dead load stress from the minimum yield and multiplying by 0.6. The dead load stress is found by using the section modulus to the bottom of the steel deck when the top of the deck is in compression of S_b. The allowable concrete stress is 0.45 f'_c. The allowable load is 157.5 PSF as opposed to that of 104 + 28 or 132 PSF in the criteria. Generally speaking, the criteria gives lower loads for long spans and higher loads for short spans than those computed by allowable stress. This is because the ultimate load varies linearly with the shear span, which is independent of the section properties.

APPENDIX

GIVEN: (1) 30' Bays, 10' Beam Centers

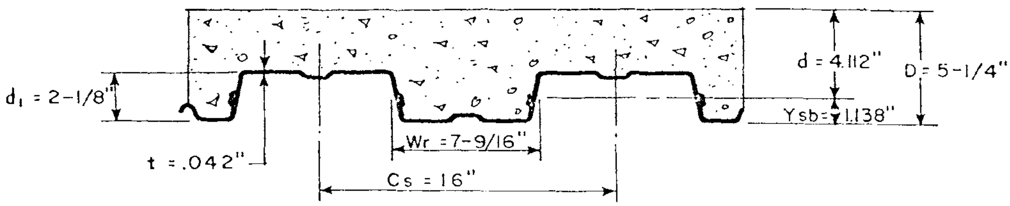
(2) Superimposed Loads

A.	Office	Live	50 PSF
		Partition	20 PSF
		Ceiling	8 PSF
B.	Corridor	Live	100 PSF
		Ceiling	8 PSF

(3) 2 Hour unprotected fire rating

USE: 5-1/4" total depth lightweight concrete

W_c = 110 lb./ft^3 n = 14 f'_c = 3000 psi



Properties Per Foot of Width:

A_s = 0.687 in^2 +S = 0.417 in^3 -S = 0.427 in^3

I = 0.503 in^4 S_b = 0.453 in^3 S_c = 1.743 in^3

S_T = 43.443 in^3 I_f = 9.632 in^4 I_c = 5.859 in^4

m = 3438   k = 0.38

CRITERIA	FORMULA	CALCULATION
Find actual stress due to dead load plus 150# concentrated load moment	f = (TPM + PCM)/ +S	f = (4717 + 3600)/.417 f = 19945 < 20000 OK (2.1.2.2)
Find ponding moment negative	$PM = \frac{8}{10} W_c \Delta_T L^2/\pi^2$	$PM = (.8)\ (110)\ (.411)\ \left(\frac{10}{\pi}\right)^2$ PM = 366 In. Lb.
Find dead load negative moment	$DLM = \frac{W_d L^2 (12)}{10}$	$DLM = (40.19)\ (10)^2\ (12)/10$ = 4823 In. Lb.
Total negative dead load moment	TNM = PM + DLM	TNM = 366 + 4823 = 5189 In. Lb.
Find 20# uniform load negative moment	$CLM = (W)\ (L^2)\ (12)/10$	$CLM = (20)\ (10)^2\ (12)/10$ = 2400 In. Lb.
Find 150# concentrated load negative moment	PCM = 150 L (12)/10	PCM = (150) (10) (12)/10 = 1800 In. Lb.
Find actual stress due to dead load plus 20# uniform load moment	f = (TNM + CLM)/-s	f = (5189 + 2400)/.427 $= 17772\ Lbs./In.^2 < 20000$
Find actual stress due to dead load plus 150# concentrated load moment	f = (TNM + PCM)/-s	f = (5189 + 1800)/.427 = 16368 < 20000
Find allowable web reaction	$P_{max} = t^2 \left[305 + 2.3 \left(\frac{N}{t}\right) - .022\left(\frac{N}{t}\right)^2 - .011\left(\frac{N}{t}\right)\right]$ A.I.S.I.3.5	$\frac{N}{t} = \frac{2.125}{.036} = 50.6$ $P_{max} = (.042)^2 \left[305 + (2.3)\ (50.6) - .022\ (50.6)^2 - .011\ (50.6)\right]$ P_{max} = 643 Lb.
Find load per foot	V = 1.1 WL $V = 1.1\ W_d L + 150$	V = (1.1) (60.19) (10) = 662 Lb. V = (1.1) (40.19) (10) + 150 = 592
Find number of webs per foot	$N_w = \frac{24}{C_s}$	$N_w = \frac{24}{16} = 1.5$

CRITERIA	FORMULA	CALCULATION
Find dead load	$W_d = 3.4\ A_s + \frac{W_c}{12}\left[d + \frac{d_1}{C_s}\left(W_T - C_s\right)\right]$	$W_d = (3.4)\ (.687) + \frac{110}{12}\left[5.25 + \frac{2.125}{16}\ (7\text{-}9/16 - 16)\right]$ $= 2.34 + 37.85$ $= 40.19\ Lbs/Ft^2$
Find ponding factor *J. Chinn - AISC Eng. Journal April - 1965	$PF = \frac{W_c L^4\ (144)}{EI\ \pi^4}$	$PF = \frac{110\ (10)^4\ (144)}{29.5 \times 10^6\ (.503)\pi^4}$ PF = .110
Find deflection due to uniform load	$\Delta_s = \frac{3\ W_d L^4 (1728)}{384\ EI}$	$\Delta_s = \frac{(3)\ (40.19)\ (10)^4\ (1728)}{(384)\ (29.5 \times 10^6)\ (.503)}$ $\Delta_s = .366$ In.
Find total deflection (2.1.2.3)	$\Delta_T = \Delta_s\left(\frac{1}{1 - PF}\right)$	$\Delta_T = .366\left(\frac{1}{1 - .11}\right)$ T = 0.411 in. L/180 = .667 In.
Find ponding moment - positive	$PM = \frac{8}{\pi}\ W_c\ \Delta_T\ \frac{L^2}{\pi^2}$	$PM = \frac{8}{\pi}\ (110)\ (.4111)\ \left(\frac{10}{\pi}\right)^2$ PM = 333 In. Lb.
Find dead load moment - positive	$DLM = \frac{W_d L^2\ (12)}{11}$	$DLM = (40.19)\ (10)^2\ (12)/11$ = 4384 In. Lb.
Total positive dead load moment	TPM = PM + DLM	TPM = 333 + 4384 = 4717 In. Lb.
Find 20# construction load positive moment	$CLM = (20)\ L^2\ (12)/11$	$CLM = (20)\ (10)^2\ (12)/11$ = 2182 In. Lb.
Find 150# concentrated load positive moment	$PCM = \frac{150\ L}{5}\ (12)$	PCM = (150) (10) (12)/5 PCM = 3600 In. Lb.
Find actual stress due to dead load plus 20# construction load moments	f = (TPM + CLM)/(+S)	f = (4717 + 2182)/.417 $f = 16544 < 20000$ OK (2.1.2.2)

CRITERIA	FORMULA	CALCULATION
Find load per web	$P = \frac{V}{N}$	$P = \frac{662}{1.5} = 441$ Lb. $<$ 643 OK
Find ultimate shear	$V_u = \phi d \left[\frac{mA_s}{3L} + 12K\sqrt{f'_c}\right]$	$V_u = (.8)\ (4.112) \left[\frac{(3438)\ (.687)}{(3)\ (10)} + (12)\ (.38)\ \sqrt{3000}\right]$ $V_u = 1080.6$ Lb./Ft.
Find live load for office Corridor not critical	$LL = \frac{1}{1.7}\left[\frac{2\ V_u}{L} - 1.4\ W_3\right]$	$LL = \frac{1}{1.7}\left[\frac{(2)\ (1080.6)}{10} - 1.4\ (28)\right]$ $LL = 104.0$ Lb./Ft.$^2 > 50$
Find allowable live load for $\Delta = \frac{L}{360}$	$\frac{L}{360} \times 12 = \frac{(5)\ WL^4\ (1728)}{384EI}$ $W = \frac{43704\ I}{L^3}$ $I = (I_c + I_f)/2$	$W = \frac{(43704)\ (I_c + I_f)}{(10)^3}$ $W = \frac{(43704)\ (5.859 + 9.632)}{1000\ (2)}$ $W = 338.5$ PSF
Check by existing criteria	$W = \frac{\left(F_y - \frac{DL}{f}\right) .6\ S_c}{1.5L^2}$ $W = \frac{.3\ f'_c\ S_T}{L^2}$	$W = \frac{\left(33000 - \frac{4717}{.453}\right) .6\ (1.743)}{(1.5)\ (10)^2}$ $W = 157.5$ PSF $W = \frac{(.3)\ (3000)\ (43.443)}{100}$ $W = 391.0$ PSF

SYMBOLS USED

A_s = Full area of steel deck (in.^{2}/ft.)

C_s = Cell spacing (in.)

$\triangle_s$ = Bending deflection due to wet concrete (in.)

$\triangle_T$ = Total deflection of deck due to wet concrete and ponding (in.)

$\emptyset$ = Capacity reduction factor

d = Effective depth of composite slab (in.)

d_1 = Depth of steel deck (in.)

D.L. f = Dead load bending stress in steel deck at the bottom fiber (Lb./in.^{2})

E = Modulus of elasticity of steel = 29.5 x 10^6 (Lb./in.^{2})

F_y = Minimum yield strength of deck (Lb./in.^{2})

f = Bending stress (Lb./in.^{2})

f'_c = 28 day concrete compressive test cylinder strength (Lb./in.^{2})

I_c = Moment of inertia of composite section based on cracked section (In.^{4}/ft. of width)

I_f = Full moment of inertia of composite section (In.^{4}/ft. of width)

I = Moment of inertia used in deflection calculations (In.^{4}/ft. of width)

k = Intercept of regression line

L = Length of span ft.

LL = Allowable superimposed live load for service conditions

CLM = Moment due to a 20 PSF uniform construction load in Lbs.

DLM = Moment due to uniform dead load of deck and concrete in Lbs.

PM = Moment of additional concrete dead load due to deflection of the deck in Lbs.

PCM = Moment of 150 Lb. concentrated load in Lbs.

TPM = Total positive construction load and dead load moments in Lbs.

TPN = Total negative construction load and dead load moments in Lbs.

m = Slope of regression line

N = Actual length of bearing for a maximum value of web depth

N_w = Number of webs per ft.

P = Load per web (Lbs.)

PF = Ponding Factor

P_{max} = Allowable load per web (Lbs.) AISI 3.5

S = Section modulus of deck (In.^{3}/ft.)

t = Steel deck thickness exclusive of coatings (In.)

V_u = Calculated ultimate shear (Lbs./ft. of width)

W = Live Load

W_c = Concrete weight (Lbs./ft.^{3})

W_d = Weight of steel deck plus concrete (Lbs./Ft.^{2})

W_r = Average Rib width (In.)

S_c = Composite section modulus to bottom of deck (In.^{3}/ft.)

S_T = Composite section modulus to top of concrete (In.^{3}/ft.)

W_3 = Dead load applied to slab exclusive of slab weight (Lbs./ft.^{2})

D = Nominal out to out depth of slab (In.)

Y_{sb} = Distance from centroidal axis of steel deck to bottom of steel deck (In.)