ANALYSIS AND DESIGN OF STEEL DECK – CONCRETE COMPOSITE SLABS

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(ABSTRACT)

As cold-formed steel decks are used in virtually every steel-framed structure for composite slab systems, efforts to develop more efficient composite floor systems continues. Efficient composite floor systems can be obtained by optimally utilizing the materials, which includes the possibility of developing long span composite slab systems. For this purpose, new deck profiles that can have a longer span and better interaction with the concrete slab are investigated.

Two new mechanical based methods for predicting composite slab strength and behavior are introduced. They are referred to as the iterative and direct methods. These methods, which accurately account for the contribution of parameters affecting the composite action, are used to predict the strength and behavior of composite slabs. Application of the methods in the analytical and experimental study of strength and behavior of composite slabs in general reveals that more accurate predictions are obtained by these methods compared to those of a modified version of the Steel Deck Institute method (SDI-M). A nonlinear finite element model is also developed to provide additional reference. These methods, which are supported by elemental tests of shear bond and end anchorages, offer an alternative solution to performing a large number of full-scale tests as required for the traditional m-k method. Results from 27 composite slab tests are compared with the analytical methods.

Four long span composite slab specimens of 20 ft span length, using two different types of deck profiles, were built and tested experimentally. Without significantly increasing the slab depth and weight compared to those of composite slabs with typical span, it was found that these long span slabs showed good performance under the load tests. Some problems with the

vibration behavior were encountered, which are thought to be due to the relatively thin layer of concrete cover above the deck rib. Further study on the use of deeper concrete cover to improve the vibrational behavior is suggested.

Finally, resistance factors based on the AISI-LRFD approach were established. The resistance factors for flexural design of composite slab systems were found to be ϕ=0.90 for the SDI-M method and ϕ=0.85 for the direct method.

In Memory of my Father
and
In Love of my Mother

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A_{bf}	= area of steel deck bottom flange / unit width of slab
A_s	= steel deck cross sectional area
A_{webs}	= area of steel deck webs / unit width of slab
a	= depth of concrete stress block
	$= \dfrac{A_s f_y}{0.85\, f_c'\, b}$ (Eqn.(3-6))
	$= \dfrac{F_s + F_{st}}{0.85\, f_c'\, b}$ (Eqn.(3-24))
b	= section width
C	= resultant of concrete compressive force
c	= depth of the neutral axis of composite section
D_n	= nominal value of dead load
d	= distance of the steel deck centroid to the top surface of the slab (effective depth)
	= length of each segment
dL, dL_i	= elongation of the bottom fiber of concrete slab of segment i
dL_c	= elongation of the segment at the mid-span
d_c	= deflection of the partially composite section
d_s	= deflection of the steel deck
E_s	= elastic modulus of steel deck
E_o, E_{sc}	= initial and secant modulus of concrete
e_1, e_2, e_3	= moment arms of T_1, T_2, T_3 (Eqn.(3-9))
F	= minimum anchorage force (Chapter 3) = $f_y\left(A_s - \dfrac{A_{webs}}{2} - A_{bf}\right)$, (Eqn.(3-8))
	= fabrication factor (Chapter 6)
F_m	= mean of fabrication factor

F_s, F_{st} = tensile force in the steel deck resulted from the effect of shear bond and end anchorages respectively

$F_{s,limit}$ = upper limit of F_s

$f_{anchorage}$ = stress in the steel deck induced by end anchorages

f_{bond} = stress in the steel deck induced by shear bond force, f_b

f_c' = concrete compressive strength

$f_{c',m}$ = mean of concrete compressive strength = $\mu_{f_c'}$

f_{cast} = stress in the steel deck induced by concrete casting

f_s = shear bond force per unit length

f_{shore} = stress in the steel deck induced by shore removal

$f_{s,max}$, $f_{s,min}$

= maximum and minimum of f_s

f_t = concrete tensile strength

f_w = stress in the steel deck induced by puddle welds

f_y = steel deck yield stress

f_{yc} = corrected steel deck yield stress due to concrete casting and shoring

f_y^* = remaining strength of the steel deck

$f_{y,m}$ = mean of steel deck yield stress = μ_{f_y}

f_1, f_2 = elastic concrete compressive and tensile stress at the extreme fiber

h_b = concrete depth above steel deck rib

h_1 = depth of the concrete flange (concrete above steel deck rib)

I_{eff} = effective cross sectional inertia of the slab

I_i = effective cross sectional inertia of a segment

i = sequence number of a segment

L = span length of the slab

L' = shear span length

L_c = cantilever length

L_n = nominal value of live load

L_s = shear bond length

M = bending moment, general (Chapter 3)

= material factor (Chapter 6)

M_{et} = first yield bending moment

M_m = mean of material factor

$M_{m,SDI}$, $M_{m,Direct}$

= means of material factor with regard to the SDI and Direct method, respectively

M_{nc}, M_{nd} = nominal moment capacity: phase-1 and phase-2, respectively

M_p = steel deck plastic moment capacity

M_u, M_n = nominal bending moment

m = bending moment caused by a unit load

N_b = $k\ f_c'\ h_b\ b$ (Eqn.(3-3))

N_r = number of shear studs / unit width of slab

n = number of segment from the support to the mid-span

P = professional factor

P_m = mean of professional factor

p_f = probability of failure

Q_i, Q_m = load effect, mean of load effect

Q_n = nominal strength of single shear stud

q, q_c, q_d = load carrying capacity: total, phase-1, phase-2, respectively

R = reduction factor due to insufficient number of shear studs

to provide anchorage = $\dfrac{N_r Q_n}{F}$

= support reaction

R_n, R_m = nominal resistance, mean of resistance

S = steel deck section modulus

s_i = total slip at a section

T = resultant of tensile force in steel deck

T_1, T_2, T_3 = forces acting in top flange, web and bottom flange of steel deck

t = steel deck thickness

t_m = mean of steel deck thickness = μ_t

u_1^d = nodal displacement of steel deck beam element in d.o.f.-1 direction (horizontal)

u_1^c = nodal displacement of concrete beam element in d.o.f.-1 direction (horizontal)

V, V_R, V_Q

= coefficients of variation: general, resistance, load effect

V_M, V_F, V_P, $V_{f_c'}$, V_{f_y}, V_t

= coefficients of variation of: material, fabrication, professional factors, concrete compressive strength, steel deck yield stress, steel deck thickness

$V_{M,SDI}$, $V_{M,Direct}$

= coefficients of variation of material factor with regard to the SDI and Direct method, respectively

V_u = ultimate shear capacity

x, x_i = distance from the support to the section being investigated

y_c = horizontal projection of y_d

y_d = depth of deck c.g. from concrete c.g.

y_s = horizontal slip of steel deck relative to the concrete

y_1, y_2 = moment arm of F_s and F_{st}, respectively

β = reliability index

ε, ε_{cu} = concrete strain, concrete strain at the peak compressive stress

ε_s = steel deck strain

Φ = standard normal probability function

ϕ = design resistance factor

γ_D, γ_L = dead and live load factors

γ_i = design load factor

γD = correction due to diagonal shear cracking

κ = fraction of the support reaction, R in Eqn.(3-11)

λ, λ_R, λ_Q = log-normal mean: general, resistance, load effect

μ = coefficient of friction between the deck and concrete

$\mu_{f_c'}$ = mean of concrete compressive strength = $f_c'{}_{,m}$

μ_{f_y} = mean of steel deck yield stress = $f_{y,m}$

μ_t = mean of steel deck thickness = t_m

θ = rotation of cross sectional plane (Chapter 4)

= central safety factor (Chapter 6)

ρ = reinforcement ratio = A_s / bd

σ, σ_P, σ_t = standard deviations: general, professional factor, steel deck thickness

$\tau_{\text{shear bond}}$ = shear bond strength

Ψ = $\left(\gamma_D \dfrac{D_n}{L_n} + \gamma_L\right) \Big/ \left(1.05\dfrac{D_n}{L_n} + 1\right)$, (Eqn.(6-18))

ζ, ζ_R, ζ_Q = log-normal standard of deviation: general, resistance, load effect

Ω_i = $\dfrac{\int_i M\,m\,ds}{\int_L M\,m\,ds}$ (Eqn.(3-22))