

# **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  $\phi=0.90$  for the SDI-M method and  $\phi=0.85$  for the direct method.

*In Memory of my Father  
and  
In Love of my Mother*

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## LIST OF NOTATIONS

$A_{bf}$	= 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 $= \frac{A_s f_y}{0.85 f_c' b} \text{ (Eqn.(3-6))}$ $= \frac{F_s + F_{st}}{0.85 f_c' b} \text{ (Eqn.(3-24))}$
$b$	= 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) = $f_y \left( A_s - \frac{A_{webs}}{2} - A_{bf} \right)$ , (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 = $\mu_{f_y}$
$f_1, f_2$	= 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 = $\frac{N_r Q_n}{F}$ = 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 = $\mu_t$
$u_1^d$	= 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
$\beta$	= reliability index
$\epsilon, \epsilon_{cu}$	= concrete strain, concrete strain at the peak compressive stress
$\epsilon_s$	= steel deck strain
$\Phi$	= standard normal probability function
$\phi$	= design resistance factor
$\gamma_D, \gamma_L$	= dead and live load factors
$\gamma_i$	= design load factor
$\gamma_D$	= correction due to diagonal shear cracking
$\kappa$	= fraction of the support reaction, R in Eqn.(3-11)

$\lambda, \lambda_R, \lambda_Q$  = log-normal mean: general, resistance, load effect

$\mu$  = coefficient of friction between the deck and concrete

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

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

$\mu_t$  = mean of steel deck thickness =  $t_m$

$\theta$  = rotation of cross sectional plane (Chapter 4)

= central safety factor (Chapter 6)

$\rho$  = reinforcement ratio =  $A_s / bd$

$\sigma, \sigma_P, \sigma_t$  = standard deviations: general, professional factor, steel deck thickness

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

$$\Psi = \left( \gamma_D \frac{D_n}{L_n} + \gamma_L \right) / \left( 1.05 \frac{D_n}{L_n} + 1 \right), \text{ (Eqn.(6-18))}$$

$\zeta, \zeta_R, \zeta_Q$  = log-normal standard of deviation: general, resistance, load effect

$$\Omega_i = \frac{\int_L M m ds}{\int_L M m ds} \text{ (Eqn.(3-22))}$$