Experimental Evaluation and Analytical Modeling of Shear Bond in Composite Slabs

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(ABSTRACT)

The strength and behavior of composite slabs are governed by the shear interaction between the concrete and the steel deck. The interaction property depends on several factors and it is not possible to express the relationship from a purely analytical basis. As such, analysis and design methods available today use the interaction property derived from full scale performance tests. In numerical modeling, the interaction property is obtained from a variety of elemental push off tests which, for the most part, do not represent actual slab bending.

This research comprises experimental, analytical and numerical investigations of composite slabs. The central objective of the experimental work is to develop a new small scale test method for evaluating the performance and behavior of composite slabs and also for determining the shear interaction property for use in numerical analysis. The characteristics of the new test specimen are simple, easy and economical to conduct, as well as comparable in performance and behavior with the more common full scale slab test.

The analytical study was conducted to determine whether data from small scale tests can be used in the present analytical methods to predict the strength of the actual slabs, to use the same test data for input in the numerical analysis, and to improve the present Partial Shear Connection (PSC) design procedure. A model that relates the shear bond stress to slab slenderness, which can be used to estimate the shear interaction property for slabs with any slenderness, was developed.

Finally, a finite element study was conducted to develop a simple modeling method that is suitable for analyzing composite slabs with variable slenderness. Parametric analyses to determine the effect of slenderness on the performance and behavior of composite slabs, and on the accuracy of the present design methods were also conducted.

The results of this investigation demonstrate that the small scale test is feasible as a replacement for the full scale test. Data from the small scale test can be used not only in the analytical methods but also in the numerical analysis, thus eliminating the need for separate push off type tests.

Keyword: composite slabs, small scale test, elemental test, partial shear connection, shear bond, steel-concrete composite

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a = depth of concrete compressive zone at full interaction, $a = \frac{A_p f_{yp}}{0.85 f_{cm} b}$

A_s = cross section area per unit width of steel deck

A_p = effective cross area of the steel deck (PSC method)

b = unit width of slab

B_b = embossment width at the bottom

B_t = embossment width at the top

d = effective slab depth measured from extreme concrete compression fiber to the centroidal axis of full cross section of steel deck

d_d = depth of profiled steel deck

d_p = effective depth of the slab (PSC method)

e = distance from the centroid of the effective area of the sheeting to its underside (PSC method)

E_c = modulus of elasticity of concrete

e_p = distance of the plastic neutral axis of the steel deck to its underside (PSC method)

E_s = modulus of elasticity of steel deck, 29500 ksi

f'_c = concrete compressive strength

f_{ck} = characteristic compressive strength of concrete (PSC method)

f_{cm} = concrete compressive strength (PSC method)

f'_{ct} = concrete compressive strength at time of slab testing

FE = finite element

F = shear bond force

FM = force equilibrium method

F_u = ultimate strength of steel sheeting

F_y = minimum yield stress of steel sheeting

f_{yp} = yield strength of the steel sheeting (PSC method)

h_c = concrete cover depth above deck top flange

h_t = total slab thickness

I_n = negative moment of inertia per unit width of steel deck (used for negative bending or for decks in inverted position)

I_p = positive moment of inertia per unit width of steel deck

I_s = moment of inertia of steel deck

k = ordinate intercept of shear bond line (*m-k* method)

l = span length

L = span length

l_f = span or shored span length (ft)

l'_i = shear span length, (in.)

L_o = overhanging length

L_s = shear span length

$L_{s(clear)}$ = clear shear span length

L_{sf} = shear span length required for full shear connection (PSC method)

L_x = distance from the support representing beam length (PSC method)

m = slope of experimental shear bond line (*m-k* method)

M = bending moment

M = moment resistance of composite slab under partial shear interaction (PSC method)

M_{pa} = plastic moment capacity of the effective cross section of the steel deck (PSC method)

M_{pr} = reduced moment capacity of the steel deck (PSC method)

$M_{p,Rd}$ = maximum resisting moment for the particular profile at full interaction (PSC method)

$M_{p,Rm}$ = moment resistance of composite slab under full interaction (PSC method)

M_r = remaining moment resistance of the steel deck when horizontal slip has occurred (PSC method)

M_{Rd} = design value of resisting bending moment in partial interaction mode (i.e. moment envelope) (PSC method)

n = modular ratio = E_s / E_c

N_b = embossment length at the bottom

N_c = concrete compressive force under partial interaction (PSC method)

N_t = embossment length at the top

p = slope of experimental shear bond-slenderness line (Eq. 6.9)

P = total applied load

P_h = embossment height

PSC = Partial Shear Connection

R = radius of curvature

s = end slip

s = ordinate intercept of shear bond-slenderness line (Eq. 6.9)

S_n = negative section modulus per unit width of steel deck (used for negative bending or for decks in inverted position)

S_p = positive section modulus per unit width of steel deck

t = steel sheeting thickness

V = reaction or vertical shear force

V_e = maximum experimental shear at failure obtained from full scale slab tests

V_n = nominal shear bond strength, lbs per ft of width

W_b = width of cell opening

W_c = width of one wave of steel deck corrugation

WM = work method

W_s = applied load at serviceability (deflection) limit (psf)

W_t = width of deck flange

W_{uf} = ultimate applied load of the full scale tests (psf)

$W_{um\text{-}k}$ = ultimate load calculated by *m-k* method (psf)

W_{uPSC} = ultimate load calculated by PSC method (psf)

W_{us} = ultimate applied load of the small scale tests (psf)

x = depth of concrete compressive zone under partial interaction (PSC method)

y_{cc} = location of composite neutral axis measured from concrete top fiber

y_{sc} = concrete crack length

z = moment arm between tension and compression force (PSC method)

α = slope of slab at right support

δ = vertical deflection

ε_y = steel yield strain

Φ = strength reduction factor

γ = coefficient for proportion of dead load added upon removal of shore

γ_{ap} = partial safety factor for profile steel sheeting (PSC method)

γ_c = partial safety factor for concrete (PSC method)

γ_v = partial safety factor for shear resistance (PSC method)

η = degree of interaction (PSC method)

μ = friction coefficient

θ = slope of slab at left support

ρ = ratio of deck area to effective concrete area, $\frac{A_s}{bd}$

τ = shear bond stress

τ_{um} = mechanical shear bond strength

$\tau_{u.Rd}$ = design value of the shear bond strength (PSC method)

$\tau_{u.Rk}$ = characteristic value of the shear bond strength (PSC method)