

Experimental Evaluation and Analytical Modeling of Shear Bond in Composite Slabs

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Keywords: Composite Slabs, Small Scale Test, Elemental Test, Partial Shear Connection, Shear Bond, Steel-Concrete Composite

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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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List of Notations

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 (<i>m-k</i> 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 (<i>m-k</i> 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-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

$\Phi =$	strength reduction factor
$\gamma =$	coefficient for proportion of dead load added upon removal of shore
$\gamma_{ap} =$	partial safety factor for profile steel sheeting (PSC method)
$\gamma_c =$	partial safety factor for concrete (PSC method)
$\gamma_v =$	partial safety factor for shear resistance (PSC method)
$\eta =$	degree of interaction (PSC method)
$\mu =$	friction coefficient
$\theta =$	slope of slab at left support
$\rho =$	ratio of deck area to effective concrete area, $\frac{A_s}{bd}$
$\tau =$	shear bond stress
$\tau_{um} =$	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)