ANSI / ASCE 3-91
ANSI / ASCE 9-91
ANSI Approved December 11, 1992

ASCE
STANDARDS

American Society of Civil Engineers

Standard for the Structural Design of Composite Slabs

ANSI/ASCE 3-91
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Standard Practice for Construction and Inspection of Composite Slabs

ANSI/ASCE 9-91
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ABSTRACT

American Society of Civil Engineers Standard for the Structural Design of Composite Slabs, ASCE Standard Practice for Construction and Inspection of Composite Slabs (ASCE 3-91 and ASCE 9-91 respectively) presents standards for the structural design and testing of composite slabs and for good construction practice and inspection procedures. In addition, commentaries on both standards are included. The "Standard for the Structural Design of Composite Slabs" (ASCE 3-91) and its "Commentary" cover such topics as loads, construction stage, strength design, service load design, test procedures, and test results evaluation. The "Standard Practice for the Construction and Inspection of Composite Slabs" (ASCE 9-91) and its "Commentary" discuss such topics as damage control, connections, concrete placement, shore removal, holes and hole reinforcement. These standards are written in such a form that they may be adopted by reference in a general building code.

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STANDARDS

In April 1980, the Board of Direction approved ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by the Society. All such standards are developed by a consensus standards process managed by the Management Group F (MGF), Codes and Standards. The consensus process includes balloting by the balanced standards committee made up of Society members and non-members, balloting by the membership of ASCE as a whole and balloting by the public. All standards are updated or reaffirmed by the same process at intervals not exceeding five years.

The following standards have been issued:

ANSI/ASCE 1-88 N-725 Guidelines for Design and Analysis of Nuclear Safety Related Earth Structures

ANSI/ASCE 2-91 Measurement of Oxygen Transfer in Clean Water

ANSI/ASCE 3-91 Standard for the Structural Design of Composite Slabs and ANSI/ASCE 9-91 Standard Practice for the Construction and Inspection of Composite Slabs

ASCE 4-86 Seismic Analysis of Safety-Related Nuclear Structures

Building Code Requirements for Masonry Structures (ACI530-92/ASCE5-92/TMS402-92) and Specifications for Masonry Structures (ACI530.1-92/ASCE6-92/TMS602-92)

Specifications for Masonry Structures (ACI530.1-92/ASCE6-92/TMS602-92)

ANSI/ASCE 7-93 Minimum Design Loads for Buildings and Other Structures

ANSI/ASCE 8-90 Standard Specification for the Design of Cold-Formed Stainless Steel Structural Members

ANSI/ASCE 9-91 listed with ASCE 3-91

ANSI/ASCE 10-90 Design of Latticed Steel Transmission Structures

ANSI/ASCE 11-90 Guideline for Structural Condition Assessment of Existing Buildings

ANSI/ASCE 12-92 Guideline for the Design of Urban Subsurface Drainage

ASCE 13-93 Standard Guidelines for Installation of Urban Subsurface Drainage

ASCE 14-93 Standard Guidelines for Operation and Maintenance of Urban Subsurface Drainage

ASCE 15-93 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)

FOREWORD

The material presented in this Standard has been prepared in accordance with recognized engineering principles. This Standard should not be used without first securing competent advice with respect to its suitability for any given application. The publication of the material contained herein is not intended as a representation or warranty on the part of the American Society of Civil Engineers, or of any other person named herein, that this information is suitable for any general or particular use or promises freedom from infringement of any patent or patents. Anyone making use of this information assumes all liability from such use. The appendices contained in this document are intended by the Steel Deck with Concrete Standards Committee to be included with the parent Standard document unless specifically exempted by building code authorities. This standards document is written in such a form that it may be adopted by reference in a general building code.

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NOTATION

a = depth of equivalent rectangular stress block, $A_s f_y / 0.85 f'_c b$, in.
A_s = cross-sectional area of steel deck, or area of negative moment reinforcing steel where used as tension reinforcement, sq. in. per ft. of width
A'_s = area of that portion of steel deck which is in compression, sq. in. per ft. of width
A''_s = area of that portion of steel deck which is in tension, sq. in. per ft. of width
b = unit width of slab, 12 in. (305 mm)[1]
B = width of slab, ft.
b_d = width of composite test slab, ft.
B_b = width of bottom flange measured at intersection of inside tangents, in.
B_t = width of top flange measured at intersection of inside tangents, in.
c_m = moment coefficient, dependent upon whether the slab is simply supported or continuous, and on distribution of loads
C = compressive force on cross section due to flexure, lbs.
C_s = cell spacing, in.
d = effective slab depth, distance from extreme concrete compression fiber to centroidal axis of the full cross section of steel deck, in.
d_d = overall depth of steel deck profile, in.
D_w = developed width of web measured to inside tangent on flanges, including end arcs, in.
e_1 = distance from C-resultant force to top of steel deck, in.
e_2 = distance from C-resultant force to mid-height of deck web, in.
e_3 = distance from C-resultant force to bottom of steel deck, in.
E = earthquake load perpendicular to slab, psf
E_c = modulus of elasticity of concrete, psi
E_s = modulus of elasticity of steel deck, 29,500,000 psi (203 000 MPa)
f = allowable stress, psi
f_b = bending stress for elastic computation, psi
f_r = modulus of rupture of concrete, psi
f_u = specified tensile strength of steel, psi
f_{ut} = measured tensile strength of steel, according to ASTM A370 [4], psi
f_y = specified or design yield point or yield strength of steel, psi
f_{yt} = measured yield strength of steel, according to ASTM A370 [4], psi
f'_c = specified compressive strength of concrete, psi
f'_{ct} = compressive test cylinder strength of concrete at time of slab testing, psi
f'_{c1} = lower usage compressive strength of concrete, used to determine V_{e1}, psi
f'_{c2} = laboratory test strength of concrete corresponding to V_{e2}, psi
h = nominal out-to-out depth of slab, in.
h_c = depth of concrete above top corrugation of steel deck, in.
h_t = out-to-out depth of slab at failure crack in test specimen, in.
I_c = moment of inertia of composite section based on cracked section, in.^{4} per ft. of width
I_d = moment of inertia of composite section considered effective for deflection computations, in.^{4} per ft. of width
I_D = moment of inertia of full steel deck section only taken about the composite cracked section neutral axis, in^4 per ft. of width
I_e = effective moment of inertia, in^4 per ft. of width
I_s = moment of inertia of steel deck based on effective width [1], in.^{4} per ft. of width
I_{sf} = moment of inertia of steel deck based on full cross sectional deck area, in.^{4} per ft. of width
I_u = moment of inertia of composite section based on uncracked section, in.^{4} per ft. of width
k = ordinate intercept of reduced experimental shear-bond line
k_u = ratio defining position of neutral axis at failure
k_1 = ordinate intercept of shear-bond line
K = bond force transfer property, $K_3/(K_1 + K_2)$
K_o = test average for M_o/M_t values
K_1 = $[d_d/7.8]^{0.5}$
K_2 = mechanical bond factor, from Eq. (D-12) or (D-15)
K_3 = slab width factor, from Eq. (D-10)
ℓ_e = length of embossment, in.
ℓ_f = length of span or shored span, ft.
ℓ'_f = length of shear span, ft.
ℓ_i = length of span or shored span, in.
ℓ'_i = length of shear span, in., for uniform load, $\ell'_i = \ell_i/4$ in.
ℓ''_i = distance between inflection points in any particular span of a continuous slab, in.
ℓ_{nf} = length of clear span, ft.

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[1] Unit width of slab in SI units shall be consistent with SI units for other terms.

ℓ_o = slab overhang at supports, in.

m = slope of reduced experimental shear-bond line

m_1 = slope of shear-bond line

M = moment due to concrete dead load, steel deck load, and construction live load, ft-lbs. per ft. of width

M_a = applied moment, ft.-lbs. per ft. of width

M_{cr} = calculated bending moment at cracking, ft.-lbs. per ft. of width

M_{ct} = calculated bending moment at first yield, ft.-lbs. per cell width C_s

M_n = nominal moment strength, ft.-lbs. per ft. of width

M_o = tested moment strength, ft.-lbs. per ft. of width

M_s = bending moment induced by shoring removal, ft.-lbs. per ft. of width

M_t = $K(M_{ct})/C_s$, bending moment, modified for bond limitations, ft.-lbs. per ft. of width

M_u = factored moment, ft.-lbs. per ft. of width

N = number of cells in test slab width

n = modular ratio, E_s/E_c

N_v = number of vertical elements in embossment pattern lengths

N_h = number of horizontal elements in embossment pattern lengths

P_e = maximum applied experimental slab load at failure obtained from laboratory tests (includes weight of loading system but not weight of slab), lbs.

$P_{\ell c}$ = concentrated construction live load on a per ft. width of deck, 150 lbs. (2.2 kN/m)

p_h = height of embossment, in.

p_s = embossment intensity factor, $12\ell_e/s$

s = center-to-center spacing of shear devices, in.; or in Appendix D, the length of repeating embossment pattern, in.

S = appropriate effective section modulus for either positive or negative bending, $in.^3/ft.$ of width

S_c = section modulus of concrete, $in.^3$

t = thickness of steel deck exclusive of coating, in.

T_B = component of tensile force resisted by bottom horizontal elements of steel deck in general strain analysis, lbs. per ft. of width

T_i = deck element tension forces with $i = 1$ to 3, lbs.

T_T = component of tensile force resisted by top horizontal elements of steel deck in general strain analysis, lbs. per ft. of width

T_w = component of tensile force resisted by web elements of steel deck in general strain analysis location of resultant force is assumed to be at mid-depth of web elements), lbs. per ft. of width

V_e = maximum experimental shear at failure obtained from laboratory tests (not including weight of slab), lbs. per ft. of width

V_{e1} = shear-bond capacity corresponding to a lower usage compressive strength of concrete, lbs. per ft. of width

V_{e2} = shear-bond capacity from laboratory test compressive strength of concrete, lbs. per ft. of width

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

V_u = factored shear force, lbs. per ft. of width

W = wind load perpendicular to slab, psf

w = average width of embossment, in.

W_d = computed uniform dead load, $(W_{dc} + W_{dd} + W_{ds})$, psf

W_{dc} = concrete dead load including additional weight of concrete due to deck deflection, psf

W_{dd} = steel deck dead load, psf

W_{ds} = superimposed uniform dead load, (additional dead load applied to slab exclusive of W_s), psf

W_ℓ = superimposed uniform live load, specified by general building code, but not greater than $W_{\ell s}$ or $W_{\ell f}$, psf

$W_{\ell c}$ = uniform construction live load, 20 psf (1.0 kN/m^2)

$W_{\ell f}$ = permissible superimposed uniform live load for flexure, psf

$W_{\ell s}$ = permissible superimposed uniform live load for shear-bond, psf

W_r = average rib width, $(C_s - B_t + B_b)/2$, in.

W_{rf} = roof live loads (see 4.11 of ASCE 7 [3]), snow loads, or rain loads, except ponding, psf

W_s = weight of slab, $(W_{dd} + W_{dc})$, psf

W_{sw} = snow load, psf

W_u = uniformly distributed factored load, psf

$W_{u\ell f}$ = permissible superimposed uniform load for flexure, exclusive of W_s, psf

$W_{u\ell s}$ = permissible superimposed uniform load for shear-bond, exclusive of W_s, psf

X = abscissa value for shear-bond determination $\rho d/\ell'_i\sqrt{f'_{ct}} = A_s/b\ell'_i\sqrt{f'_{ct}}$

y_{cc} = distance from neutral axis of composite section to top of slab, in.

y_{cs} = distance from neutral axis of composite section to centroidal axis of steel deck, in.

y_{sb} = distance from centroidal axis of steel deck to bottom of steel deck, in.

Y = ordinate value for shear-bond determination $= V_e/bd\sqrt{f'_{ct}}$

α = coefficient for modifying I_u for deflection calculations

β_1 = 0.85 for concrete with $f'_c \leq 4000$ psi (28 MPa) and is reduced at a rate of 0.05 for each 1000 psi (7 MPa) of strength above 4000 psi (28 MPa), but β_1 shall not be taken less than 0.65

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

Δ = maximum deflection, in.

Δ_i = iterative total deflection based on Δ to account for ponding or for the additional concrete due to the deflection of the steel during casting, ft.

Δ_1 = maximum single span deflection, in.

Δ_2 = maximum double span deflection, in.

Δ_3 = maximum triple span deflection, in.

$\epsilon_{B1}, \epsilon_{B2}, \epsilon_{B3}, \epsilon_{B4}$ = strain in bottom fiber of steel deck for general strain analysis, microinches per in.

ϵ_C = maximum compressive strain in the concrete, taken as 0.003 in./in. (0.003mm/mm)

$\epsilon_{C2}, \epsilon_{C3}, \epsilon_{C4}$ = strain at top fiber of concrete for general strain analysis, microinches per in.

$\epsilon_{T1}, \epsilon_{T2}, \epsilon_{T3}, \epsilon_{T4}$ = strain at top fiber of steel deck for general strain analysis, microinches per in.

$\epsilon_{W1}, \epsilon_{W2}, \epsilon_{W3}, \epsilon_{W4}$ = strain in web sections of steel deck taken at mid-depth of web elements for general strain analysis, microinches per in.

θ = web angle, degrees

λ = multiplier for additional long-time deflection

ρ = reinforcement ratio of steel deck area to effective concrete area, A_s/bd

ρ_b = reinforcement ratio producing balanced strain conditions

ϕ = strength reduction factor

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American Society of Civil Engineers Standard for the Structural Design of Composite Slabs

CHAPTER 1 - GENERAL

1.1 - Introduction

1.1.1 - **Composite slabs.** Composite slab construction is defined as a system comprising of normal weight or lightweight structural concrete placed permanently over cold-formed steel deck in which the steel deck performs the dual role of acting as a form for the concrete during construction and as positive reinforcement for the slab during service.

Steel decks, either shored or unshored, shall provide adequate strength and stiffness to support wet concrete and construction live loads as defined in Section 2.2.3. Composite behavior results when the steel deck has some reliable mechanical means of providing positive interlocking between the deck and the concrete. These connecting means shall provide resistance to separation of the steel deck and the concrete. Where manufacturers' decks provide for variable spacing of the shear devices, this must be accounted for in the design and test procedures.

1.1.2 - **Objective and scope.** This Standard[1] presents provisions applicable to composite slabs, relating to:

(a) structural design, and
(b) testing.

Standard performance tests shall be conducted to evaluate the load-carrying capacity of composite slabs, wherein the steel deck manufacturer shall be responsible for conducting, under supervision of a registered professional engineer and an independent testing agency, slab tests as required in Chapter 3 of this document. Steel deck section properties shall be calculated according to the AISI **Specification for the Design of Cold-Formed Steel Structural Members** [1][2] unless otherwise required herein. The ACI **Building Code Requirements for Reinforced Concrete, ACI 318** [2] shall be used for the design of composite slabs, unless modified herein. Both shored and unshored installations are considered.

The appendices contained in this design standard shall be included as part of this mandatory document unless specifically exempted by the building code authorities.

1.1.3 - **Inch-pound units.** Equations appearing in this Standard are compatible with the following Inch-Pound units. However any consistent measurement units such as SI units may be used.

(a) Force: lbs.
(b) Span length: in. or ft.
(c) Shear span length: in. or ft.
(d) Dimensions of cross section: in.
(e) Moment: ft.-lbs.

SI units or equations as given in parentheses in this Standard and Appendix A are for information only and are not part of the Standard.

1.2 - Materials

1.2.1 - **Steel deck.** Grades of steel used in fabricating steel deck units shall be as described in Section A3 of the AISI **Specification for the Design of Cold-Formed Steel Structural Members** [1]. The deck coating shall be appropriate to the environment of the structure and shall be specified by the designer.

1.2.2 - **Concrete.** Materials for concrete, including admixtures and reinforcing, shall comply with Chapter 3 of ACI 318, except as modified herein [2]. Minimum specified compressive strength of concrete, f'_c, shall be 2500 psi (17 MPa) [2]. Structural concrete shall be in accordance with ACI 318 [2].

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1 For standard practices of construction and inspection, see ASCE 9 **Standard Practice for Construction and Inspection of Composite Slabs** (See REFERENCES in Commentary)

2 Numbers in brackets denote APPLICABLE DOCUMENTS listed after Chapter 3.