New ASCE Standards for Cold-formed Steel Deck Slabs

Max L. Porter

Eleventh International Specialty Conference on Cold-Formed Steel Structures
St. Louis, Missouri, U.S.A., October 20-21, 1992

NEW ASCE STANDARDS FOR COLD-FORMED STEEL DECK SLABS

by Max L. Porter*

ABSTRACT: This paper presents highlights of the newly approved and printed ASCE Standard on the design and construction of composite floor deck slabs utilizing cold-formed steel. In 1992 four documents are being published including the following:

- "Standard for the Structural Design of Composite Slabs"--ASCE3-92,
- "Standard Practice for Construction and Inspection of Composite Slabs"--ASCE9-92, and
- A separate commentary on each of the two above Standards.

These above four documents stem from a previously published ASCE Standard entitled "Specifications for the Design and Construction of Composite Slabs" and the associated commentary thereon. The Steel Deck with Concrete Committee of the ASCE Standards Division Program has been the committee responsible for the development of these standards. The committee is continuing to work on a third standard on the diaphragm design of floor slabs utilizing cold-formed steel decking with concrete.

The paper presents the results and highlights of the accepted two standards and will discuss the status and potential items for inclusion in the proposed new diaphragm standard. Also, the presentation will give summary highlights of the ASCE standards progress in the future development of the standards program.

*Professor of Civil Engineering, Iowa State University, Ames, IA, USA

NEW ASCE STANDARDS FOR COLD-FORMED STEEL DECK SLABS

INTRODUCTION

New standards for composite steel deck with concrete have been developed as part of the standards program of the American Society of Civil Engineers (ASCE). These standards have been developed by the Steel Deck with Concrete Standards Committee under Management Group F of ASCE. The new standards divide, modify, and supplement the first standards produced entitled "Specifications for the Design and Construction of Composite Slabs" (1).

Four new documents are scheduled for publication by ASCE during the summer of 1992. These documents are:

- "Standard for the Structural Design of Composite Slabs" (2)
- "Standard Practice for Construction and Inspection of Composite Slabs" (3)
- "Commentary on the Standard for the Structural Design of Composite Slabs" (4)
- "Commentary on the Standard Practice for Construction and Inspection of Composite Slabs" (5)

An additional two documents are under development on new standards on Diaphragm Steel Deck Slabs With Concrete and a corresponding commentary thereon. This paper focuses on the highlights of the new documents being published and discusses current work under progress for the changes in next editions of the new standards.

COMPOSITE DECK STANDARDS

The first standard published in 1985 (1) as well as the four standards documents (2-5) being published in 1992 all deal with cold-formed steel decking as composite reinforcing for concrete slabs. This composite deck action is achieved by either embossments, transverse wires, holes, profile geometry or other means to interlock the steel deck and the concrete. The more common composite action utilized by the deck sections currently on the market is achieved by rolling embossments on the top, bottom or inclined (web) portions of the deck plate elements.

All of 1992 standards documents as well as the first standard address criteria for composite action after the concrete has hardened utilizing the steel deck as reinforcement for the positive bending curvature. The non-composite criteria apply prior to the concrete hardening in which case the deck serves as a form for the concrete and a working surface during construction. For these non-composite criteria, the standards reference the "Specification for the Design of Cold-formed Steel Structural Members" published by the American Iron and Steel Institute (6) for allowable steel stress, deflections, and other criteria prior to the composite action.

The Standards documents contained in References 1-5 apply to composite deck applications which have gained in popularity over the years so that today the composite steel deck slab is the most popular floor slab system for steel framed buildings. This popularity is due to the many advantages of steel deck floors, e.g.:

- positive bending reinforcement for the floor slab,
- form the conrete,
- little or no shoring,
- little formwork (only subdivisional or edge formwork is needed),
- less chance of fire,
- working platform,
- easily platized and shipped,
- easily handled and placed, and
- progression of construction to upper floors without waiting for previous floors to reach a certain concrete strength.

Shoring is needed when long spans are designed for which case the AISI Specifications are utilized (6).

For the sake of brevity in this paper, the new standard "Standard for the Structural Design of Composite Slabs" will be termed as the "Design Standard", and the new Standard "Standard Practice for Construction and Inspection of Composite Slabs" will be called the "Construction Standard".

DESIGN STANDARD

General

The new design standard has resulted from a split of the previous standard into two parts--one for design-and one for construction-oriented items. The new design standard is written in mandatory language whereas the construction standard is principally a non-mandatory written standard.

All of those items pertaining to design in the first standard (1) were retained and placed into the new design standard. Several new items have been incorporated as will be discussed in subsequent subsections; however, prior to presenting the new items, a brief summary coverage will be made in the next subsection.

Current Design Criteria

The basic philosophy of design for steel deck slabs was retained from the previous standard (1) as summarized briefly below. For example, the shear-bond design strength as based upon a standard test was retained.

The basic shear-bond design mode strengths are:

$$\phi V_n = \phi \left[bd \left(\frac{m \rho d}{l'} + k \sqrt{f'_c} \right) + \frac{\gamma W_s \, l}{2} \right] \qquad (1)$$

or

$$\phi V_n = \phi \left[bd \left(\frac{m \rho d}{3l} + k \sqrt{f'_c} \right) + \frac{\gamma W_s l}{2} \right] \tag{2}$$

where ϕ = strength reduction factor; V_n = nominal shear-bond strength, lbs. per ft. of width; b = unit width of slab, 12 in. (305 mm); d = effective slab depth, distance from extreme concrete compression fiber to centroidal axis of the full cross section of the steel deck, in.; m = slope of reduced experimental shear-bond line; ρ = reinforcement ratio of steel deck area to effective concrete area, A_s/bd; ℓ' = length of shear span, in.; for uniform load, ℓ' = 12 ℓ/4, in.; k = ordinate intercept of reduced experimental shear-bond line; f'_c = specified compressive strength of concrete, psi; γ = coefficient for proportion of dead load added upon removal of shore; and W = wind load perpendicular to slab, psf.

These equations are based upon the obtaining of a reduced slope and intercept of a linear regression of the key parameters as illustrated in Fig. 1.

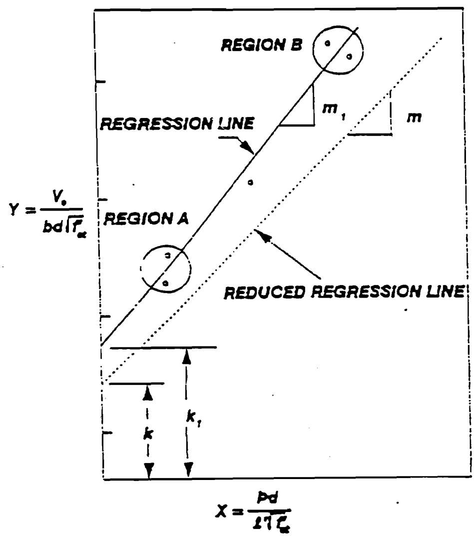

Fig. 1. Shear-Bond Strength Determination

The experimental strength values are obtained from a standard simple beam test.

Other design modes for possible under-reinforced or over-reinforced flexural capacities usually control less than approximately 4% of the applications. Most of the under-reinforced flexural cases can be handled by the conventional equation:

$$M_u = \frac{\phi A_s f_y}{12} [d - a/2] \tag{3}$$

where M_u = factored moment, ft.-lbs. per ft. of width; ϕ = strength reduction factor; 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; f_y = specified or design yield point or yield strength of steel, psi; d = effective slab depth, distance from extreme concrete compression fiber to centroidal axis of the full cross section of the steel deck, in.

However, other flexural cases must utilize a general strain analysis from compatibility of strains, equilibrium and composite superposition as depicted below:

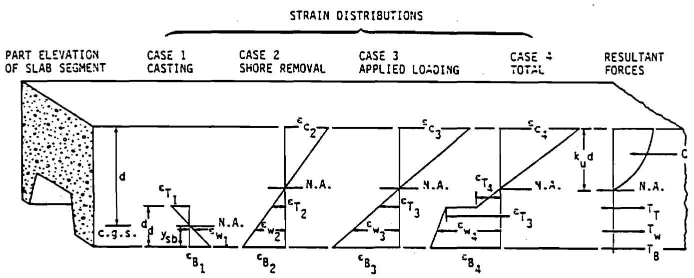

Fig. 2. Strain diagrams used to obtain general strain-computed flexural capacity of slab elements.

The general strain criteria as illustrated in Figure 2 for the most part has been shifted to the Commentary for the new design standard and the former Appendix B from the first Standard (1) has been removed and placed in the design Standard Commentary document.

New Load and ϕ Factors

To be consistent with the other standard, the load factors in the new design standard use the ones taken from the ASCE-7 document "Minimum Design Loads for Buildings and Other Structures" (7). As an example, the more common combination of dead and live loads has a 1.2 multiplier on dead loads and a 1.6 factor on live loads so the strength design loads, W_u, would be:

$$W_u = 1.2\ W_D + 1.6\ W_L \tag{4}$$

where W_D is the dead load and W_L is the live load. The corresponding strength reduction factors, ϕ, were reduced in the new design standard to accomodate the reduced load factors so that the combined factor of safety remained approximately the same. The ϕ factors are summarized below for the various design modes:

Mode	ϕ
Shear-bond	0.75
Flexure (underreinforced)	0.85
Flexural (underreinforced when $f_u/f_y \leq 1.08$)	0.65
Flexure (overreinforced)	0.70
Flexure (plain concrete)	0.60

New Strength Formulations Alternative

A new strength formulation procedure was placed in Appendix E of the new design standard as an alternative to the strengths presented in the design standard. This Appendix is of help to a manufacturer developing a new deck section within the restrictions listed below:

- must be an embossed deck,
- webs of the deck must be inclined in the range of 55-90°,
- embossment depth is in the range of 0.035 and 0.105 inches,
- the depth of deck is $\leq$ 3.0 inches,
- the cell spacing repeats at 12-inch intervals,
- no re-entrant bends in the deck's cross-section, and
- the concrete's compressive strength must fall in the range of 2500-6000 psi.

The criterion contained in Appendix E is based upon the work by Luttrell of West Virginia University (8, 9). The estimated predicted shear force capacity is generally given by the following equations:

$$M_t = K\ M_{et}/(12/C_s) \tag{5}$$

where $K = K_3/(K_1 + K_2)$

where M_t = $K(M_{et})/C_s$, bending moment, modified for bond limitations, ft.-lbs. per ft. of width; K = bond force transfer property, $K_3/(K_1 + K_2)$; M_{et} = calculated bending moment at first yield, ft.-lbs. per cell width C_s; C_s = cell spacing, in.; K_3 = slab width factor, from Eq. (E-10); $K_1 = [d_d/7.8]^{0.5}$; K_2 = mechanical bond factor, from Eq. (E-12) or (E-15) in Ref. (2).

with the remaining detailed expressions given in Appendix E of the design standard (2). The capacity obtained by this alternative must be verified by at least three confirmatory tests for:

- each deck profile, and
- each embossment pattern for:
- at least two steel thicknesses with:
- at least two deck width sections

using the simple beam test procedure as required for the shear-bond criterion.

Acceptance Criteria for In-Place Floors

A new section was included for determining the strength of existing floor systems, when needed. The standard provides provisions for loading an existing structural composite deck floor by placing at least 85% of the factored loads. The load shall be maintained for 24 hours and monitored with deflection measurements.

CONSTRUCTION STANDARD

General

As indicated previously, the new Construction Standard was divided from the first Standard (1). The significant aspect of this new Construction Standard is that the format is done in a non-mandatory style of a standard.

Some of the significant items continued from the previous standard include:

- tolerances,
- materials specification references for steel deck and concrete,
- connections,
- shore removed at 0.75 f_c',
- hole reinforcement, and
- concrete construction criteria.

Inspection

One of the significant additions to the Construction Standard is the inclusion of a short section providing for inspection of composite steel decking during the various phases of construction, including delivery of the deck. The essential part of the inspection is that the deck that is delivered to the job site is essentially the same or better than that which was tested for the design strength determination.

Measurements and Tolerances

To aid in the inspection process (as well as the testing phases) an appendix was added which provides for the delineation of the measurements, the measurement points, and the defined measurements to be taken on a composite deck section. These measurement definitions are important due to the various curvatures, embossments, etc. encountered with composite decks.

Along with the measurement and inspection criteria, a set of various important tolerances are included. Examples of these measured tolerances are:

- dimensions of shear transfer devices at -10%,
- depth of embossments at -10%, and
- spacing of shear devices at ± 1/4 in.

Conduits in Slab

New provisions have been included for conduits that are included or placed in the concrete portions of the slab. An example of this criteria is a conduit of one inch or less in diameter with no crossovers must be spaced at least 18 inches apart.

WORK IN PROGRESS

Diaphragm Standard

A subcommittee of the ASCE's "Steel Deck with Concrete Standards" committee is working on a new Standard for steel deck with concrete for diaphragm floor or roof slabs. This standard is based upon the research work at Iowa State University (10-12) for composite diaphragms plus proprietary and other previous diaphragm research. Some topics for possible inclusion include a standard strength criteria, stiffness calculations, and connector strengths needed. Possible separation into various failure mode considerations is being developed. A possible standard test may be included for certain conditions. Also, Luttrell's work for steel deck diaphragms will be considered (13).

Concentrated Floor Loads

Special provisions have been discussed by the ASCE's "Steel Deck with Concrete" committee for handling the design and analysis for floor slabs subjected to concentrated loads. These loads have been divided into heavy or large and moderate concentrated loads. The procedures by Porter (for large point loads) (14), and the European standards are being considered for large and moderate, respectively.

Other Items

Several items are on this committee's list for further development or resolution resulting from discussions and input on the code issues w.r.t. these new standards. In short form, these items are tabulated below:

- coordination with factors used by the Steel Deck Institute and the ASCE Standards,
- make the Inspection criteria mandatory,
- make the Construction Standard a mandatory document,
- determine a concrete compressive strength for a particular class of floor based

upon intended use and exposure,
- give criteria or suggestions for jointing considerations and crack width criteria for over interior supports,
- provide more criteria detail for load and deflection criteria for the Section 3.4 on insite strength test determinations,
- provide criteria for a minimum bearing length of deck on the support,
- work out compatibility with the ACI Standard practice and ACI 318 Standards, and
- provide detail definition and criteria of when the composite starts and solve issues of when is composite action okay to use for loads or for shore removal.

Shrinkage and Temperature Alternatives

One of the major items of controversy for the new design standard was the issue of allowing polypropylene fibers as a satisfactory alternative for the current provisions for shrinkage and temperature reinforcement. This issue was included in several drafts, but the lack of resolution of negative ballots resulted in its being removed in this edition of the Standard. Alternative shrinkage and temperature reinforcing is an issue that will be considered by the Steel Deck with Concrete for a possible change to the next Standards document.

SUMMARY

The two new standards documents summarized in this paper provide for design and construction criteria of composite deck floor slabs. These documents along with an associated commentary on each are scheduled for printing in 1992. An additional standard on diaphragm steel deck with concrete slabs is in the development process. Several left-over topics that could not be completed in the latest standards documents are in progress for possible additions or changes for the next edition.

REFERENCES

1. ASCE Steel Deck with Concrete Committee, Specifications for the Design and Construction of Composite Slabs, published by Technical Council of Codes and Standards, Division of the American Society of Civil Engineers, New York, NY, 1985.

2. ASCE 3-92, Standard for the Structural Design of Composite Slabs, American Society of Civil Engineers, Steel Deck with Concrete Standards Committee of Management Group F, Codes and Standards, 345 East 47th Street, New York, NY, 10017-2398.

3. ASCE 9-91, Standard Practice for Construction and Inspection of Composite Slabs, American Society of Civil Engineers, Steel Deck with Concrete Standards Committee, 345 East 47th Street, New York, NY, 10017-2398, July 1991.

4. Porter, M. L., with input from Steel Deck with Concrete Committee, Commentary on the Standard for the Structural Design of Composite Slabs, Standard published by

American Society of Civil Engineers, July 1992.

5. Porter, M. L., with input from Steel Deck with Concrete Committee, Commentary on the Standard Specifications for the Construction and Inspection of Composite Slabs, Standard published by American Society of Civil Engineers; several drafts, list one completed July 1992.

6. Specification for the Design of Cold-Formed Steel Structural Members, American Iron and Steel Institute, 1133-15th Street, N.W., Washington, D.C., 20005, August 19, 1986, with December 11, 1989 addendum.

7. ASCE 7-88, Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers, 345 E. 47th Street, New York, NY 10017 (formerly ANSI A58.1-1982, American National Standards Institute, Inc., New York, New York, 10017-2398), 1989.

8. Luttrell, L. D., "Methods for Predicting Strength in Composite Slabs", Proceedings of 8th International Specialty Conference on Cold-Formed Steel Structure, University of Missouri-Rolla, Rolla, MO, pp. 419-431, 1986.

9. Luttrell, L. D., "Strength Formations for Composite Slabs", Proceedings of 7th International Specialty Conference on Cold-Formed Steel Structure, University of Missouri-Rolla, Rolla, MO, pp. 307-326, 1984.

10. Porter, M. L., Easterling, W. S. and Dodd, S. M., "Earthquake Resistance of Composite Floor Diaphragms", Report submitted to the National Science Foundation, Washington, D.C., October 1, 1985.

11. Porter, M. L. and Easterling, W. S., "Proposed Design Techniques for Composite Diaphragm Slabs", Proceedings ASCE Structures Congress, Orlando, Fla., August 19, 1987.

12. Easterling, W. S. and Porter, M. L., "Composite Diaphragm Behavior and Strength", Proceedings of Ninth Specialty Conference on Cold-Formed Steel Structures, St. Louis, MO, Nov. 1988.

13. Luttrell, L. D., Diaphragm Design Manual, 2nd Ed., Steel Deck Institute, Canton, OH, 1987.

14. Porter, M. L., "Two-Way Analysis of Steel-Deck Floor Slabs", Published in Proceedings of Ninth Specialty Conference on Cold-Formed Steel Structures, St. Louis, MO, Nov. 1988.