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Highlights of New ASCE Standard on Composite Slabs

by

MAX L. PORTER

INTRODUCTION

In the summer of 1985, a new standard entitled "Specifications for the Design and Construction of Composite Slabs" (1) was published by ASCE's Technical Council on Codes and Standards. In addition, a commentary manual was also published in a combined booklet (2). These documents provide a complete design standard for cold-formed composite steel decking used as reinforcement in floor slabs.

Research commenced at Iowa State University (ISU) in 1967, sponsored by the American Iron and Steel Institute, towards providing a basis for the new standards. Subsequent ISU research has been sponsored by several industry makers of composite steel deck and by the National Science Foundation. The research has been continuous from 1967 to present with the most recent work being conducted on diaphragm (in-plane shear) slabs reinforced with cold-formed steel decking.

This paper and, in particular, the oral presentation of this conference provides a summary and highlights of the key aspects of the newly published "Specifications for the Design and Construction of Composite Slabs and "Commentary on Specifications for the Design and Construction of Composite Slabs" (1) and associated Commentary (2). Since the newly published standard is available from the American Society of Civil Engineers, only some of the key provisions will be summarized in this paper. Anyone using these criteria needs the complete standard from ASCE.

BACKGROUND

Composite steel deck slabs have continued to gain in popularity to where today they are one of the more predominant means of floor slab construction in most typical buildings. The term "composite steel deck floor slab" is applied to systems in which the steel deck has some means of providing positive interlock between the deck and the concrete. A typical system is shown in Figure 1.

The mechanical means of providing positive interlocking for composite steel deck systems is achieved by one of the following means:

(1) Embossments and/or indentations,
(2) Transverse wires attached to the deck,
(3) Holes in the deck, and
(4) Deck profile and surface bonding.

The positive interlocking provides resistance to vertical separation and to horizontal slippage between the steel deck and the concrete surfaces.

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The popularity of the steel-deck-reinforced floor slabs has stemmed from many advantages. Two of the principal advantages are that (1) the steel deck serves the floor slab reinforcement with only additional shrinkage in temperature reinforcement needed, and (2) the steel deck eliminates the need for most formwork with only minor subdivision formwork needed. In addition, the steel deck formwork feature saves a considerable amount of labor and the steel deck provides a ceiling surface for easy attachments. In some cases the deck systems have been designed to contain pre-engineered ducting for electrification, communication, and air distribution. Safety is a key element in the construction process since the deck provides a safe working platform for the workman and the likelihood of construction fires is greatly reduced. An important feature is that the time of construction is greatly reduced since the casting of additional floors may proceed without waiting for previously fabricated floors to gain strength.

For those steel deck sections where a closed cell is desired or a flat ceiling surface is needed, a sheet of steel is attached to the bottom plate corrugation elements to provide what is called a "cellular" deck section. This is illustrated in Figure 1. Those deck profiles not containing the extra steel sheet are termed "non-cellular" decks.

At present there exists 119 different steel deck cross sections available from 13 major manufacturers in the United States. A complete compulation of these deck sections and manufacturers is contained in a set of course notes developed by the author of this paper. (3) At the present time, a short course is being sponsored by ASCE at various major city locations in the United States to present the new standards.

An extensive theoretical experimental investigation for research on composite steel deck floor slab systems commenced in 1967 under the direction of Dr. Carl E. Ekberg of Iowa State's Engineering Research Institute with the sponsorship of the American Iron and Steel Institute. This research has led to an investigation by the author of many aspects of cold-formed steel-deck-reinforced slabs resulting in more than 850 full-scale tests. Many of these tests have been funded by the National Science Foundation and various steel deck manufacturers. Table 1 lists the general types of tests conducted at ISU.

Many publications have resulted from this research at Iowa State University and other sources. Some of the publications are contained in References 4-30. Most of the references pertain to the findings from the extensive research testing program sponsored by the American Iron and Steel Institute. Additional research was sponsored by several steel deck manufacturers and recently by the National Science Foundation. References 21-23, 26-29 are examples of work being currently conducted at Iowa State University to investigate the in-plane shear diaphragm action of composite steel-deck-reinforced slab structures. The newly published standards, however, pertain to the composite steel-deck-reinforced slabs subjected to gravity loading. The results of the research on diaphragm action has not yet been formulated to be included in the new standard.

The newly-published ASCE standard on Composite Steel-Deck Floor Slabs encompasses provisions from several other standards and specifications.
Table 2 contains a listing of the referenced specifications and sources of information from other documents utilized as part of the ASCE standards. Of paramount importance to this list are the first two items in that the "Specification for the Design of Cold-Formed Steel Structural Members", published by the American Iron and Steel Institute, applies to the steel deck prior to the curing and strength gain of the concrete. After the concrete has gained sufficient strength, the composite slab is designed utilizing many of the provisions applicable to the reinforced concrete practice as published by the American Concrete Institute given in Item 2 in Table 2.

COLD-FORMED STEEL DECK CONSIDERATIONS

Composite cold-formed steel deck sections are utilized to carry the loads due to the wet concrete and construction live and dead loads prior to the concrete curing and strength gain. The specifications published by AISI as listed in Item 1 of Table 2 are utilized as the criteria for determining the design of these steel deck sections.

The maximum steel stresses in the deck for bending, shear, and bearing caused by the above-mentioned dead and live loads as computed by elastic theory. Section 2.1.2.1 of the ASCE standards stipulates that the steel stresses should not exceed 0.6 x fy or 36 ksi (248 MPa), whichever is the lesser, under the combined weights of the wet concrete, deck and the construction live loads. The construction live loads are given as either 20 lbs. per square foot (958 Pa) or 150-lb (667 N) concentrated load on a one foot (0.305 m) of width.

The loads should be applied in a manner that simulates the sequence of concrete placement. The resulting deflections on the weight of the steel deck and subsequent loading is limited to 12L/180 or 3/4 inch (19 mm), whichever is smaller.

Several tolerances for the fabrication of the steel deck sections are given in the new ASCE standards. For example, the uncoated steel thickness shall not be less than 95% of the design thickness. Also, the spacing of the shear devices shall not vary by more than ± 1/4 inch. (6.35 mm). In addition, the dimensions and the depths of embossments or indentations shall not be more than 10% under the design value.

COMPOSITE STEEL-DECK SLAB CONSIDERATIONS

Once the concrete has been placed, cured, and gained sufficient strength, the slab is designed utilizing many of the concepts applicable to reinforced concrete design. Strength design concepts are utilized for this composite slab design. That is, load factors are applied to the dead and live loads; for example,

\[ W_u = 1.4 (W_1 + W_3) + 1.7 LL \]  \hspace{1cm} (1)

where \( W_1 \) = weight of slab \( (DL_d + DL_c) \)

\( W_3 \) = additional dead weight applied to the slab

exclusive \( W_1 \)
Other load factor combinations are presented in the ASCE standards.

Together with the load factors, strength reduction factors, $\phi$, are utilized. The $\phi$ factors vary according to failure mode as indicated:

- **Shear-Bond**
  - Strength reduction factor: 0.80

- **Flexure (underreinforced)**
  - Strength reduction factor: 0.90

- **Flexure (underreinforced for nonductile steel)**
  - Strength reduction factor: 0.70

- **Flexure (overreinforced)**
  - Strength reduction factor: 0.75

- **Flexure (plain concrete)**
  - Strength reduction factor: 0.65

The load factors together with the $\phi$ factors incorporate the total factor of safety for the composite steel-deck-reinforced slab design. The $\phi$ factor is multiplied times the strength equation prediction and the load factor is multiplied times the expected load.

The strength formulations are based upon the anticipated modes of failure. The three modes of failure utilized in the new ASCE standard are as follows:

- **Shear-bond**
- **Flexure**
  - underreinforced
  - overreinforced

Since over 95% of the designs for steel-deck slabs are based upon the shear-bond mode of failure, the shear-bond strength is presented first in the standards, and should receive first priority, followed by flexure.

**Shear-Bond Strength**

Due to the fact that so many different kinds of steel-deck profiles and composite deck shear device styles are manufactured, a determination of the basic shear-bond strength is necessary through the use of a simple beam-type of test. This simple type of performance test is illustrated in Figure 2. The key test parameters and observations to be observed from the performance tests are listed below:

- Deck type and profile
- Shear span, $L'$
- Concrete properties, $f_c'$, etc.
- Steel deck properties, $A_S$, $I_S$, etc.
- Dead load
- Ultimate load
- Failure mode
- Specimen dimensions, $L$, $D$, $b$, etc.
- Shear device, spacing, and dimensions
- Deflection and slip behavior

The purpose of these performance tests is to determine the shear-bond strength of composite steel-deck slabs.
The shear-bond mode of failure is characterized by the formation of the diagonal tension crack in the concrete at or near one of the load points, followed by loss of bond between the steel deck and concrete. See Figure 3. This simultaneous loss of bond results in an observable slip between the steel and the concrete at the end of the span. The slippage results in a loss of composite action over the beam segment, referred to as the shear span length, L'. Physically, the shear span is the distance from the support reaction to the concentrated load. The research test program conducted at Iowa State University (indicated by the references earlier) indicate that the shear-bond mode of failure is the one more likely to occur for most steel-deck slab systems.

The end-slip usually occurs as the ultimate failure load, $P_\text{e}$, is reached and is followed by a significant drop in loading (if hydraulic testing apparatus is used). Some steel deck systems exhibit small amounts of end slip prior to reaching ultimate load. End slip normally occurs at only one end of the specimen. Generally the end slip is less than 0.06 inches (1.5 mm) at ultimate load and is associated with increased deflections and some creep. In some cases, the test engineer will need to use judgement as to the correct ultimate load, $P_\text{e}$, to use for the evaluation of the steel deck system.

The most important items to obtain from the shear-bond test are those key parameters needed to determine a linear shear-bond plot that best fits the data in order to establish a slope, m, and intercept, k, needed for Equations 6 and 7 (shown in Equations (2) and (3) below) of Section 2.2.1.5.1 of the ASCE standards. These key parameters are lumped together to be $V_\text{e}/bd\sqrt{f_{ct}}$ as ordinate values and $\rho d/L'\sqrt{f_{ct}}$ plotted as abscissa values. This shear-bond strength determination plot of these key parameters is shown in Figure 4.

The criteria for determination of the specimens for these slab-element performance tests is outlined in Chapter 3 of the new ASCE standards. In general, specimens needed to determine the shear-bond strength as indicated in Figure 4, should have a wide enough range of parameters to determine a good representative regression line. These parameters should encompass the complete range of depths and span lengths anticipated to be marketed by the particular steel deck manufacturer.

Writing the straight line equation from Figure 4 results in equation indicated in Section 2.2.1.5.1 for the determination of shear-bond strength as indicated below:

$$V_\text{u} \leq \phi V_\text{n}$$

where

$$\phi V_\text{n} = \phi \left[ 12d \left( \frac{m_0 d}{L'} + k \sqrt{f_{ct}} \right) + \frac{W_1 L}{2} \right]$$

For a uniformly applied load, Equation (2) becomes,

$$\phi V_\text{n} = \phi \left[ d \left( 4\frac{m_0 d}{L} + 12k \sqrt{f_{ct}} \right) + \frac{W_1 L}{2} \right]$$

Equations (2) and (3)
where,

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

\( m \) = slope of the reduced experimental shear-bond line

\( k \) = ordinate intercept of the reduced experimental shear-bond line

\( f_{c'} \) = specified compressive strength of concrete, psi

\( L' \) = shear span, in.; for uniform load, \( L' = \) one quarter of the span

\( L \) = length of span, ft

\( W_1 \) = weight of slab \((DL_d + DL_c)\), psf

\( \phi \) = strength reduction factor (\( \phi = 0.8 \) for shear-bond)

\( \rho \) = reinforcement ratio of steel deck area to effective concrete area

\( A_s \) = cross-sectional area of steel deck where used as tension reinforcement

\( b \) = unit width of slab = 12 in. (305 mm)

\( \gamma \) = coefficient for proportion of dead load added upon removal of shore

Since shoring contributes a reaction load to the composite section upon removal of the shore support, the method of handling the amount of this force in the overall determination of the design equation is very important. Figure 5 illustrates the procedure for the determination of a factor called gamma, which is utilized in Equations 2 and 3 above. The ASCE standard contains a table listing the other shoring factors. The one illustrated in Figure 5 is the most common if shoring is used, and, of course, if no shoring is used, than the \( \gamma \) factor is zero.

Based upon Equation 1, the permissible designed uniform live load can then be obtained by solving for the shear-bond predicted live load \((LL)\) as determined from:

\[
LL = \frac{1}{1.7} \left[ \frac{2\phi V_n}{L} - 1.4 \left( \gamma W_1 + W_3 \right) \right]
\]

where \( \phi V_n \) is determined by either Equation 2 or Equation 3.

**Flexure**

Composite steel-deck slabs subject to flexure failure are generally classified as underreinforced or overreinforced slabs depending on the amount of the steel reinforcement ratio, \( \rho = A_s / bd \). The ratio that denotes a balance condition is:

\[
\rho_b = \frac{0.85 \beta_1 f_{c'}'}{f_y} \left[ \frac{88,500(D - D_d)}{(88,500 + f_y)d} \right]
\]

where the new terms are:

\( \beta_1 \) = 0.85 for concrete with \( f_{c'}' \leq 4,000 \) psi (27,560 kPa) and reduced at a rate of 0.05 for each 1,000 psi (6,890 kPa) of strength exceeding 4,000 psi (27,560 kPa)

\( f_y \) = specified yield point or yield strength of steel

\( D \) = nominal out-to-out depth of slab

\( d_d \) = overall depth of steel deck profile

\( d \) = effective slab depth

Slabs which have a reinforcement ratio less than or equal to that which produces balanced conditions are considered to be underreinforced, whereas
slabs with a reinforcement ratio greater than that given by Equation 5 are considered overreinforced.

The nominal moment strength, $M_n$ is determined for an underreinforced slab by the following equation:

$$ M_u \leq \phi M_n = \frac{A_s f_y}{12} \left( d - \frac{a}{2} \right) $$

where the new terms are:

- $M_u$ = required moment strength
- $a = \frac{A_s f_y}{0.85 f_c b}$
- $M_n$ = nominal moment strength

Equation 6 is used for slab cross-sections capable of developing the full-yield stress across the entire deck depth. In some instances, strain compatibility of the cross-section or ductility of the steel does not permit a yielding across the section. The above equation is not considered valid for decks consisting of a low ductile grade of steel, defined where $f_u/f_y$ is less than 1.08. Also, the above equation does not account for supplementary steel in addition to the steel deck. In cases where the steel deck cross-section is partially in compression, Equation 6 does not apply. For cases when Equation 6 does not apply a general strain analysis shall be performed (as outlined in Appendix B of the Standards). The determination of the nominal moment strength for the overreinforced flexure mode is also found by general strain analysis.

The flexural live load determination is again based upon Equation 7:

$$ LL = \frac{1}{1.7} \left[ \frac{\phi M_n}{c m L^2} - 1.4 (W_1 + W_3) \right] $$

Deflection Limitations

Deflection limitations are based upon the concepts of cracked and uncracked transformed cross-sections similar to that for reinforced concrete. The steel is transformed to an equivalent concrete area, after which conventional elastic theory is applied to determine the moments of inertia of a cross-section. The effective moment of inertia used for deflection calculations is taken as a simple average of the cracked and uncracked sections. The maximum allowable computed deflections under service loads are very similar to those taken for conventional reinforced concrete in accordance with the American Concrete Institute 318 Specifications as listed in Table 2.

SHRINKAGE AND TEMPERATURE REINFORCEMENT

The minimum shrinkage reinforcement in the form of transverse bars having a yield strength of at least 60,000 psi (413 MPa) or wire welded fabric must be provided. The minimum area of this shrinkage and temperature reinforcement is equal to 0.00075 times the area of the concrete above
the steel-deck section, but not less than 0.028 square inches per foot (0.71 mm/.3 m).

CONSTRUCTION PRACTICE

Chapter 4 of the ASCE standards gives special provisions concerning construction practice. Only examples will be highlighted. Such as the fact that the steel deck shall be free of soil, debris, oil, standing water, loose mill scale or coating and all other foreign matter. The deck must have adequate bearing and fastened so as to provide a safe working platform during the construction phases.

Each deck sheet is fastened to a supporting member through one interior rib so an average spacing of the fasteners along the supports is not more than 12 inches (305 mm). The side laps between the sheets of the deck shall be sufficient to control differential deflections and be capable of carrying a concentrated load of 200 lbs (890 N) applied to the lower sheet.

Planking should be placed on the deck to prevent damage from concrete buggies and other equipment during the construction phases. Temporary shore supports shall not be removed until concrete strength has gained at least 0.75 of the $f_c'$ design strength. Large holes shall have proper structural framing around the hole so as to provide load transfer across the section.

CONCLUSIONS

A summary of the highlights for the newly published American Society of Civil Engineer's Standards has been presented. The new standard is entitled "Specifications for the Design and Construction of Composite Slabs" and is available from ASCE.
REFERENCES


10. Porter, M. L., and Ekberg, C. E., Jr., "Investigation of Cold-Formed Steel-Deck Reinforced Concrete Floor Slabs", Proceedings of First Specialty Conference on Cold-Formed Steel Structures, Department of Civil Engineering, University of Missouri-Rolla, August 19-20, 1971.

11. Porter, M. L., and Ekberg, C. E., Jr., "Behavior of Concrete slabs Reinforced with Three-Inch Deep Cold-Formed Steel Decking", Oral Presentation given by Ekberg at Second Specialty Conference on Cold-Formed Steel Structures, Department of Civil Engineering, University of Missouri-Rolla, Rolla, Missouri, October 1973.

13. Porter, M. L., and Ekberg, C. E., Jr., "Design vs. Test Results for Steel Deck Floor Slabs", Proceedings of Third International Specialty Conference on Cold-Formed Steel Structures, University of Missouri-Rolla, 1975.


24. Porter, M. L., and Ekberg, C. E., Jr., "Coating Effects of Cold-Formed Steel Deck Slabs," Fifth International Specialty Conference on Cold-Formed Steel Structures, St. Louis, Mo., pp. 369-386, November 1980.


Table 1. Types of Tests Conducted at Iowa State University (ISU)

- One-way slab elements
- Pushout
- Elements with deck transverse to span length
- Continuous slab elements over more than one span
- Fatigue
- Elements constructed with variable supplementary reinforcement
- Elements of various surface coatings
- Two-way slabs subjected to concentrated loads
- Shoring conditions
- Uniform versus concentrated loading
- Two-way slabs subjected to diaphragm loads
- Two-way slabs subjected to combined gravity and diaphragm loads
- Push-off specimens
- In-plane shear elements
- Slabs with stud restraint
Table 2. References Used in New Standards


2. ACI Manual of Concrete Practice, 1984, American Concrete Institute, Box 19150, Redford Station, Detroit, Michigan 48219.
   ACI 211.1-81 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
   ACI 211.2-81 Standard Practice for Selecting Proportions for Structural Lightweight Concrete
   ACI 301-84 Specifications for Structural Concrete for Buildings
   ACI 304-73 Recommended Practice for Measuring, Mixing, Transporting and Placing Concrete (Reaffirmed 1983)
   ACI 305R-77 Hot Weather Concreting (Revised 1982)
   ACI 306R-78 Cold Weather Concreting
   ACI 318-83 Building Code Requirements for Reinforced Concrete
   ACI 318R-83 Commentary on Building Code Requirements for Reinforced Concrete


   ASTM A370-77 Standard Methods and Definitions for Mechanical Testing of Steel Products (editorial changes 1979, 1980)
   ASTM C39-81 Standard Test Methods for Compressive Strength of Cylindrical Concrete Specimens

   AWS A5.1-81 Specifications for Carbon Steel Covered Arc Welding Electrodes
   AWS A5.5-81 Specifications for Steel Lowalloy Covered Arc Welding Electrodes
   AWS D1.3-81 Specifications for Welding Sheet Steel and Structures
### Appendix.—Notation

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Depth of equivalent rectangular stress block, ((A_s f_y)/(0.85 f_c' b)), in.</td>
</tr>
<tr>
<td>(A_s)</td>
<td>Cross-sectional area of steel deck or area of negative moment reinforcing steel where used as tension reinforcement, in.²/ft of width</td>
</tr>
<tr>
<td>b</td>
<td>Unit width of slab = 12 in.</td>
</tr>
<tr>
<td>(c_m)</td>
<td>Moment coefficient, dependent upon whether the slab is simply supported or continuous and on distribution of loading</td>
</tr>
<tr>
<td>d</td>
<td>Effective slab depth (distance from extreme concrete compression fiber to centroidal axis of the full cross section of the steel deck), in.</td>
</tr>
<tr>
<td>(D_{Lc})</td>
<td>Concrete dead load, psf</td>
</tr>
<tr>
<td>(D_{Ld})</td>
<td>Steel deck dead load, psf</td>
</tr>
<tr>
<td>(f_u)</td>
<td>Specified tensile strength of steel, psi</td>
</tr>
<tr>
<td>(f_y)</td>
<td>Specified or design yield point or yield strength of steel, psi</td>
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<tr>
<td>(f_c')</td>
<td>Specified compressive strength of concrete, psi</td>
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<tr>
<td>(I_c)</td>
<td>Moment of inertia of composite section based on cracked section, in.⁴/ft of width</td>
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<tr>
<td>(I_d)</td>
<td>Moment of inertia of composite section considered effective for deflection computations, in.⁴/ft of width</td>
</tr>
<tr>
<td>(I_u)</td>
<td>Moment of inertia of composite section based on uncracked section, in.⁴/ft of width</td>
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<tr>
<td>(k)</td>
<td>Ordinate intercept of reduced shear-bond line</td>
</tr>
<tr>
<td>(k_l)</td>
<td>Ordinate intercept of shear-bond line</td>
</tr>
<tr>
<td>L</td>
<td>Length of span, ft</td>
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<tr>
<td>(L')</td>
<td>Length of shear span, in.; for uniform load, (L' = ) one quarter of the span</td>
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<tr>
<td>LL</td>
<td>Allowable superimposed live load for service conditions, psf</td>
</tr>
<tr>
<td>(M_n)</td>
<td>Nominal moment strength, ft-lbs/ft of width</td>
</tr>
<tr>
<td>Symbol</td>
<td>Definition</td>
</tr>
<tr>
<td>--------</td>
<td>------------</td>
</tr>
<tr>
<td>$M_u$</td>
<td>Required moment strength, ft-lbs/ft of width</td>
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<tr>
<td>$m$</td>
<td>Slope of reduced shear-bond line</td>
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<tr>
<td>$m_1$</td>
<td>Slope of shear-bond line</td>
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<td>$V_u$</td>
<td>Required shear strength, lbs/ft of width</td>
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<tr>
<td>$W_1$</td>
<td>Weight of slab ($DL_d + DL_c$), psf</td>
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<tr>
<td>$W_2$</td>
<td>Construction dead plus live loads ($DL_d + DL_c + LL_c$), psf</td>
</tr>
<tr>
<td>$W_3$</td>
<td>Dead load applied to slab, exclusive of $W_1$, psf</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>Equals 0.85 for concrete with $f'_c \leq 4000$ psi and is reduced at a rate of 0.05 for each 1000 psi of strength above 4000 psi, but $\beta_1$ shall not be taken less than 0.65</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Coefficient for proportion of dead load added upon removal of shore</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Strength reduction factor</td>
</tr>
<tr>
<td>$\phi M_n$</td>
<td>Design moment strength based on flexural failure, ft-lbs/ft of width</td>
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<tr>
<td>$\phi V_n$</td>
<td>Design strength based on shear-bond failure, lbs/ft of width</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Reinforcement ratio of steel deck area to effective concrete area, $A_s/bd$</td>
</tr>
<tr>
<td>$\rho_b$</td>
<td>Reinforcement ratio producing balanced conditions</td>
</tr>
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</table>
Fig. 1  Typical building floor construction utilizing cold-formed steel decking with composite support beams.
Fig. 2. Typical arrangement for testing one-way slab elements.
Fig. 3. Typical shear-bond failure.
Fig. 4. Typical shear-bond plot showing the reduced evaluation of $m$ and $k$. 

\[ \frac{V_e}{bdYf_{ct}} \quad \frac{pd}{L'Vf'_{ct}} \]
Fig. 5. Illustration of determination of $y$.