STEEL DECK INSTITUTE

AMERICAN NATIONAL STANDARDS INSTITUTE/ STEEL DECK INSTITUTE

T - CD - 2022 Test Standard for Composite Steel Deck-Slabs

Approved American National Standard

ANSI

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Since hazards may be associated with the handling, installation, or use of steel deck and its accessories, prudent construction practices should always be followed. The Steel Deck Institute recommends that parties involved in the handling, installation or use of steel deck and its accessories review all applicable manufacturers' material safety data sheets, applicable rules and regulations of the Occupational Safety and Health Administration and other government agencies having jurisdiction over such handling, installation or use, and other relevant construction practice publications.

Preface

(This Preface is not part of the SDI T-CD-2022, *Test Standard for Composite Steel Deck-Slabs*, but is included for informational purposes only.)

This Standard is based upon past successful usage, advances in the state of knowledge, and changes in practice. The Steel Deck Institute *Test Standard for Composite Steel Deck-Slabs*, SDI T-CD-2022, provides a method for testing performance of composite steel deck-slabs, and for analyzing the test data. It replaces earlier editions of the SDI T-CD Standard.

This Standard has been developed as a consensus document to provide a uniform practice in the testing of composite steel deck-slabs.

The Symbols to this Standard are an integral part of the Standard. A non-mandatory Commentary has been prepared to provide background for the Standard provisions and the user is encouraged to consult it. Additionally, non-mandatory User Notes are interspersed throughout the Standard to provide concise and practical guidance in the application of the provisions.

The user is cautioned that professional judgment must be exercised when data or recommendations in the Standard are applied, as described more fully in the disclaimer notice preceding this Preface.

Table of Contents

Symbols

Some definitions in the list below have been simplified in the interest of brevity. In all cases, the definitions given in the body of the Standard govern. Symbols without text definitions, or used only in one location and defined at that location, are omitted in some cases. The section or table number in the right-hand column refers to the Section where the symbol is first used.

Symbol	Definition	Section
b_d	Width of composite test slab, in. (mm)	D4.2
C_p	Correction factor	G2
C_ϕ	Calibration coefficient	G2
d_d	Overall depth of steel deck profile, in. (mm)	D4.2
e	Natural logarithmic base	G2
f'_c	Concrete cylinder compressive strength, psi (MPa)	D4.3
F_m	Mean value of the fabrication factor	F2
F_y	Measured yield strength of steel, ksi (MPa)	D4.3
F_u	Measured tensile strength of steel, ksi (MPa)	D4.3
h	Overall depth of the composite slab, measured from bottom of deck to top of concrete, in. (mm)	D4.2
h_t	Overall depth of composite slab at failure crack, measured from bottom of deck to top of concrete, in. (mm)	D4.2
l	Length of span, measured from center of supports, in. (mm)	D2
l'	Length of shear span, in. (mm)	D2
M_m	Mean value of the material factor	F2
n	Number of tests	G2
P_m	Mean value of the professional factor	G2
R_a	Allowable strength for ASD	G1
R_n	Nominal strength	E2
R_t	Tested strength of composite steel deck-slab test assembly	E3
R_u	Required strength for LRFD	G1
t	Base metal thickness, in. (mm)	D4.2
V_F	Coefficient of variation of fabrication factor	F2
V_M	Coefficient of variation of material factor	F2
V_P	Coefficient of variation of test results	E2
V_Q	Coefficient of variation of load effect	G2
β_0	Target reliability index	G2
ϕ	Resistance Factor (LRFD)	G1
Ω	Safety Factor (ASD)	G1

Replaces ANSI/SDI T-CD-2017

SECTION A - General Provisions

A1 Scope, Applicability, and Units

A1.1 Scope

This Test Standard for Composite Steel Deck-Slabs shall apply to testing of composite steel deck-slabs under load transverse to the deck span, and the determination of the nominal resistance and stiffness thereof.

The User Notes and Commentary shall not be part of the Standard.

User Note: User Notes and Commentary are intended to provide practical guidance in the use and application of this Standard.

For composite steel deck-slabs for which the flexural strength controlled by deck-to-concrete bond is determined by SDI SD Section F3.2.2, *shear bond testing* shall be performed in accordance with this Standard.

For composite steel deck-slabs which require *confirmatory testing*, testing shall be performed in accordance with this Standard.

A1.2 Units of Symbols and Terms

Equations that appear in this Standard are compatible with the US Customary System (USCS) of units. However, any consistent system of units shall be permitted to be used. SI units or equations shown in parenthesis in this Standard are for information only and are not part of this Standard.

User Note: The USCS is also referred to as English Units or the inch-pound system.

A2. Reference Codes, Standards, and Documents

The following documents or portions thereof are referenced in this Standard and shall be considered part of the requirements of this Standard. Where these documents conflict with this Standard, the requirements of this Standard shall control:

1. American Iron and Steel Institute (AISI)
   a. AISI S100-16 w/S2-20 (2020), North American Specification for the Design of Cold-Formed Steel Structural Members.
2. ASTM International (ASTM)
   a. ASTM E4-16, Standard Practices for Force Verification of Testing Machines
   b. ASTM A370-17a, Standard Test Methods and Definitions for Mechanical Testing of Steel Products

c. ASTM C39/C39M-18, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
d. ASTM E6-15e1, Standard Terminology Relating to Methods of Mechanical Testing

3. American Concrete Institute (ACI)
   a. ACI 318-19, Building Code Requirements for Structural Concrete
4. Steel Deck Institute (SDI)
   a. SDI-SD-2022, Standard for Steel Deck

A3. Definitions

Terms which are not defined in this Standard, but are defined in SDI SD or AISI S100, shall have the meaning as defined in SDI SD or AISI S100. Terms not defined in this Standard, SDI SD nor AISI S100 shall have the ordinary accepted meaning for the context for which they are intended.

***Approved Agency*:** A qualified registered professional engineer, firm, or corporation approved by the reviewing authority to conduct the testing and provide the reports required by this Standard.

***Configuration*:** An arrangement of a specific assembly of profile, thickness, mechanical properties, span, fill type and thickness that is unique to that test.

Confirmatory Testing: Tests made on composite deck-slab members designed in accordance with the SDI-SD Standard using rational engineering analysis.

Prototype Composite Deck-Slab System: A composite deck-slab system, including a range of *configurations* that provide various combinations of profile, thickness, mechanical properties, span, fill type and thickness.

***Single Composite Deck-Slab Configuration (Single Configuration)*:** A composite deck-slab having a specific *configuration* with one set of profile, thickness, mechanical properties, span, fill type and thickness.

***Shear Bond Testing*:** Testing performed to establish shear bond performance as required by SDI-SD Section F3.2.2.

A4. Precision

The load measuring device shall be calibrated in accordance with ASTM E74 to a Class A rating or better.

Loads shall be recorded to a precision of 2 percent of the anticipated ultimate load during application of test loads. Deflections shall be recorded to a precision of 0.01 in. (0.25 mm).

SECTION B - Test Specimen

B1 Concrete

B1.1 Concrete used in the composite specimens shall be prepared and cured in accordance with standard construction practice in accordance with Chapter 5 of ACI 318.

B1.2 Concrete used in the composite specimens shall be representative of the compressive strength and unit weight of the concrete in the actual field installation. Structural normal weight concrete and structural lightweight concrete shall be permitted.

B1.3 Compression strength of the concrete shall be determined in accordance with ASTM C39. A minimum of three concrete cylinders shall be tested for each identical set of test specimens. Testing of the cylinders shall be performed within 24 hours of the testing of the composite specimens. Concrete cylinders shall be cured under the same ambient conditions as the test specimens.

B2 Steel Deck Units

B2.1 The coating of all steel deck units shall be in a condition which simulates the condition found in actual field installation.

B2.2 The steel deck units shall be representative of the units in the end-use construction, including profile of the steel deck, deck embossment pattern, deck thickness, steel tensile properties, and all other properties that affect the strength and stiffness of the steel deck.

B2.3 Standard tensile tests of the steel from which the deck units were produced shall be conducted in accordance with ASTM A370. A minimum of three steel coupons shall be tested for each identical set of test specimens.

B3 Dimensions and Construction of Composite Specimens

B3.1 Span

Test specimen spans shall be representative of the range of spans used in field applications for the deck profile tested. Single span, 2-span or 3-span specimens shall be permitted.

B3.2 Composite Steel Deck Construction Joint

Two and three span tests shall have a butt joint in the steel deck at minimum of one interior support of the test. A lap joint shall be permitted to be used in lieu of a butt joint when that is representative of the intended method of construction.

B3.3 Width

Width of all specimens shall not be less than 2 feet (600 mm), unless the width of a single deck panel is less than 2 feet (600 mm), in which case a narrower single width panel shall be permitted. It shall be permitted for specimens to be wider than the width of a single panel.

B3.4 Depth

Slab depths shall be representative of the range for which the deck unit shall be utilized.

B3.5 Fasteners

Support and side-lap fastener type, size, and installation shall be representative of the actual field installation. Fastener installation shall be in accordance with SDI-SD.

B3.6 Slab End Details

Slab end details (including fastening) and shear stud installation (if any) shall be representative of the actual field installation. The distance from the centerline of the support fastener to the end of the deck unit shall not be greater than the depth of the deck unit, unless the minimum allowable edge distance for the specific fastener requires a larger distance.

B3.7 Shoring

The test specimen shall be permitted to be shored or unshored during concrete placement and curing.

B3.8 Moving of Test Specimens

Test specimens shall be permitted to be moved after the concrete has been placed. Specimens which are moved shall be supported in a manner such that the integrity of the specimen is not compromised.

SECTION C - Test Configuration

C1 Test Support Frame

C1.1 Single-Span Test

The test support frame shall consist of two exterior steel supports.

User Note: Either wide-flange beam support is shown in Commentary Figure C1.1-1, or bar stock is shown in Commentary Figure C1.1-2.

C1.2 Two-Span or Three-Span Test

The test support frame shall consist of two exterior steel supports and either one (two span test) or two (three span test) interior steel supports. It shall be permitted to vary span lengths within an individual test specimen, however the length of any exterior span for a three span test shall not be less than 50% of the length of the interior span, nor shall the shorter span of a two-span test be less than 50% of the length of the longer span.

User Note: A multi-span *configuration* is shown in Commentary Figure C1.2-1.

The end of unloaded spans shall be restrained to resist upward movement relative to the support. It is permitted to use a support beam or bar roller above the specimen to restrain this upward movement.

C1.3 Frame Width

The test frame shall be wide enough to accommodate the width of the test specimen.

C1.4 Supports and Load Application Beams

Steel supports and load application beams shall have a minimum bearing width of 4 inches (100 mm), a maximum bearing width of 6 inches (150 mm), a minimum bearing thickness of ¼ inch (6 mm), and a maximum bearing thickness of 1 inch (25 mm). Supports shall be sufficiently stiff to provide a uniform reaction across the width of the specimen. Rollers and pins shall be permitted under steel supports.

SECTION D - Test Procedure

D1 Concrete Strength at Testing

Testing shall be conducted after the concrete has reached its specified compressive strength, but not less than seven days after casting. Except as noted, structural lightweight concrete shall be permitted a longer curing time if required. High early strength concrete shall be permitted to be tested earlier than seven days.

D2 Application of Load

Specimens shall be tested using concentrated line loads. It shall be permitted to insert a bearing material, such as rubber or grout, between the reaction beam and test specimen to ensure uniform contact.

Alternatively, uniform loading shall be permitted to be used with l' equal to the distance from the support to the intersection of the first vertical flexural crack with the bottom of the deck, but need not be less than $l/4$. Uniform loading using air bags, vacuum boxes, or other means shall be permitted as an alternate to concentrated line loads, provided that the test method does not provide stiffening to the test specimen.

User Note: Commentary Figures C1.1-1 and C1.1-2 illustrate line loads.

D3 Loading

D3.1 Initialization

Prior to testing, it is permissible but not mandatory to apply a small initial pre-load. Before beginning testing, all measuring devices shall be zeroed.

D3.2 Rate of Loading

All loads shall be applied continuously and without shock, except for pauses to take instrument readings. All load shall be applied in maximum increments of one-tenth of the anticipated ultimate load. Load shall be applied at a maximum rate of 10% of the anticipated ultimate load per minute.

D4 Recording of Data

The following data shall be recorded and documented for each test specimen.

D4.1 Testing Properties

a. Maximum applied load, including weight of all test equipment and frames that add to the applied load on the specimen
b. Load versus deflection measurements, with deflection measured at location(s) of

anticipated maximum deflections

c. Brief description of significant events during testing

d. Identification of final mode and details of failure

e. Date and place of testing, along with the name of the witness(es) and *approved agency* overseeing the testing

D4.2 Dimensional Properties (Measured)

a. Width of composite test slab, b_d

b. Overall depth of slab, h, (measurements shall be taken on an interior rib and edges of the specimen, at ends, center, and load points)

c. Depth of steel deck unit, d_d

d. Length of span, *l*

e. Length of shear span, *l'*

f. Base metal thickness, measured from specimens used to obtain material properties, t

g. Overall depth of slab at failure crack, h_t

h. Embossment length, width, depth, spacing and general variation in these dimensions

i. Slab overhang at support

D4.3 Material Properties (Measured)

a. Concrete cylinder compressive strength, f'_c

b. Yield strength of steel, F_y

c. Tensile strength of steel, F_u

d. Percent elongation of steel

e. Steel specification and grade

D4.4 Dead Loads

a. Steel deck dead load (calculated or measured)

b. Concrete dead load (including concrete ponding load due to deck deflection, either calculated or measured)

D4.5 Construction of Test Specimen

a. Steel surface coating and conditions

b. Shoring

c. Details of end restraint (if any), including thickness, cross section profile, dimensions, and attachment details

d. Details of shear connectors (if any), support fasteners, and side-lap fasteners (if any), including type, size, and spacing

e. Concrete mix design and date of casting

f. Type and location of steel reinforcing (if any)

g. Concrete curing procedures

h. Concrete cylinder air-dry density at time of testing (measured)

SECTION E - Evaluation of Strength of a Single Composite Deck-Slab Configuration

E1 Application

The strength of a *single composite deck-slab configuration* shall be permitted to be determined in accordance with this section.

E2 Number of Tests and Evaluation

Evaluation of the test results shall be made on the basis of the average value of test data resulting from tests of not fewer than three identical specimens, provided the deviation of any individual test result from the average value obtained from all tests does not exceed ±20 percent. If such deviation from the average value exceeds 20 percent, more tests of the same kind shall be made until the deviation of any individual test result from the average value obtained from all tests does not exceed ±20 percent or until at least three additional tests have been made.

No test result shall be eliminated unless a rationale for its exclusion is given.

The effect of removal of shoring (if any), shall be considered in the evaluation of the results.

The average value of all tests made shall then be regarded as the nominal strength, R_n, for the series of the tests. R_n and the coefficient of variation V_P of the test results shall be determined by statistical analysis.

The resistance factor or safety factor shall be determined in accordance with Section G.

E3 Variation of Properties

Consideration shall be given to any variation of differences between the specified properties and the actual properties of the tested *configurations*. When analyzing single deck-slab *configuration* by average strength, the factors in Table E3-1 shall be used to adjust the tested strength of each *configuration*. When using the rational engineering analysis model, the adjustment factors in Table E3.1 shall be applied to the tested strength unless the analysis model includes provisions that adjust for the characteristics included in Table E3-1.

Table E3-1 Adjustment Factors

Limit State	Parameter	$R_{n\ design}$ [1]
Yielding	$t > t_{design}$	$(t_{design} / t)\ R_t$
	$F_y > F_{y\ design}$	$(F_{y\ design}/F_y)\ R_t$
	$d_d > d_{d\ design}$	$(d_{d\ design} / d_d)\ R_t$
Horizontal Shear or End Slip	$d_d > d_{d\ design}$	$(d_{d\ design} / d_d)\ R_t$
	$f'_c > f'_{c\ design}$	R_t [2]
All	design > test	R_t

[1] When more than one parameter applies, the combined multiplier shall be applied to R_t.

[2] The compression strength of the concrete has been shown to not significantly influence the shear bond strength.

User Note: Table E3-1 is intended to be used to adjust when the design parameters of the intended product (F_y for instance) differ from the tested *configuration*.

SECTION F - Evaluation of Strength of a Composite Deck-Slab System by Confirmatory Testing

F1 Application

The strength of a composite deck-slab system by *confirmatory testing* shall be permitted to be determined by testing in accordance with this section.

User Note: Testing under this Section may be used to develop shear bond strength to be used in SDI SD Section F3.2.2.

F2 Number of Tests and Evaluation

Evaluation of an analytical or empirical theory to a range of *configurations* shall be based on the ratio of the test results to the analytically predicted value for that *configuration*. No fewer than three *configurations* shall be tested. The *configurations* shall include the maximum and minimum conditions covered by the analytical theory.

The strength is determined within parameters varied in the testing. Extrapolation outside of the tested parameters is not permitted. For each parameter being evaluated, (a) all other parameters shall be held constant, and (b) the nominally selected values of the parameter to be tested shall not bias the study to a specific region of the parameter.

No test results shall be eliminated unless a rationale for their exclusion is given.

The effect of removal of shoring (if any), shall be considered in the evaluation of the results.

The resistance factor or safety factor shall be determined in accordance with Section G.

The correlation coefficient, C_c, between the tested strength (R_t) and the nominal strength (R_n) predicted from the rational engineering analysis model shall be greater than or equal to 0.80.

Dimensions and material properties shall be measured for all test specimens. The as-measured dimensions and properties shall be used in determination of the calculated nominal strength [resistance] ($R_{n,i}$) as employed in determining the resistance factor or safety factor in accordance with Section G.

The specified dimensions and properties shall be used in the determination of the calculated nominal strength for design. The bias and variance between the as-measured dimensions and properties and the nominally specified dimensions and properties shall be reflected in the selected material (M_m, V_M) and fabrication (F_m, V_F) factors per Section G2. Otherwise, the selected values of M_m and F_m shall not be greater than in Section G2, and the values of V_M and V_F shall not be less than the values given in Section G2.

SECTION G - Determination of Resistance Factor and Safety Factor

G1 Design Strength

The strength of the tested assembly shall satisfy Equation G1-1 or Equation G1-2 as applicable.

$$R_u \le \phi R_n \quad \text{for LRFD} \qquad \text{(Eq. G1-1)}$$

$$R_a \le R_n / \Omega \quad \text{for ASD} \qquad \text{(Eq. G1-2)}$$

G2 Resistance Factor

The resistance factor, ϕ, shall be calculated using Equation G2-1.

$$\phi = C_\phi (M_m F_m P_m) e^{-\beta_o \sqrt{V_M^2 + V_F^2 + C_P V_P^2 + V_Q^2}} \qquad \text{(Eq. G2-1)}$$

Where:

C_ϕ = Calibration coefficient
= 1.50

M_m = Mean value of the material factor
= 1.10

F_m = Mean value of the fabrication factor
= 1.00

P_m = Mean value of the professional factor
= 1.00 when evaluating the strength of a *single composite deck-slab configuration* in accordance with Section E

= $\dfrac{\sum_{i=1}^{n} \dfrac{R_{t,i}}{R_{n,i}}}{n}$ when evaluating shear bond strength of a *prototype composite deck-slab system*

Where:

i = Index of tests
= 1 to n

n = Total number of tests

$R_{t,i}$ = Tested strength [resistance] of test i

$R_{n,i}$ = Calculated nominal strength [resistance] of test i per shear bond model

e = Natural logarithmic base
= 2.718

β_0 = Target reliability index
= 2.5

V_M = Coefficient of variation of material factor
= 0.10

V_F = Coefficient of variation of fabrication factor
= 0.05
C_p = Correction factor
= $((1 + (1/n))(n-1)) / (n-3)$ for $n \geq 4$
= 5.7, for $n = 3$
V_P = Coefficient of variation of test results
=

$$\frac{1}{R_m}\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(R_i - R_m)^2} \geq 0.065$$

Where:
R_i = Each R_t if all test assemblies are identical and an average tested strength is used
= $R_t / R_{n\ theory}$ if comparing a theoretical equation to a range of tests
R_m = Mean value of all test results, R_t, if all test assemblies are identical and an average tested strength is used
= Mean of all $(R_t / R_{n\ theory})$ if comparing a theoretical equation to a range of tests
n = number of tests
V_Q = Coefficient of variation of load effect
= 0.21
Cc = Correlation coefficient

$$= \frac{n\Sigma R_{t,i}R_{n,i} - (\Sigma R_{t,i})(R_{n,i})}{\sqrt{n(\Sigma R^2_{t,i}) - (\Sigma R_{t,i})^2}\sqrt{n(\Sigma R^2_{n,i}) - (\Sigma R_{n,i})^2}}$$

Where:
i = Index of tests
= 1 to n
n = Total number of tests
$R_{t,i}$ = Tested strength [resistance] of test i
$R_{n,i}$ = Calculated nominal strength [resistance] of test i per shear bond model
R_n = Average value of all test results

G3 Safety Factor

The safety factor, Ω, shall be calculated using Equation G3-1.

$$\Omega = 1.50 / \phi \qquad \text{(Eq G3-1)}$$

User Note: Section G3 is intended to be used for gravity loading only and is not applicable to diaphragms. The safety factor is calculated using an effective load factor of 1.50, which is applicable for a ratio of live to dead load of approximately 3.

SECTION H - Report

H1 Preparation of Report

The test report shall be prepared by an *approved agency* who shall have supervised the assembly and testing of the test specimens.

H2 Minimum Information Included in Report

1. The test report shall include a description of the tested specimens, including a drawing detailing all pertinent dimensions. This information shall, at a minimum, include the information listed in Sections D4.2, D4.3, D4.4, and D4.5.
2. The test report shall include a detailed drawing of the test setup, depicting location and direction of load application, location of displacement instrumentation and their point of reference, and details of any deviations from the test requirements stipulated in Sections B, C and D. Photographs shall be permitted to supplement the detailed drawings of the test setup.
3. The test report shall include individual and average load-versus-deflection values and curves, as plotted directly, or as reprinted from data acquisition systems.
4. The test report shall be permitted to include theoretical load-versus-deflection curves using both uncracked and fully cracked section properties.
5. The test report shall include individual and average maximum test load values observed, description of the nature, type and location of failure exhibited by each specimen tested, and a description of the general behavior of the test fixture during load application. Photographs shall be permitted to supplement the description of the failure mode(s).
6. The test report shall include a description of the test method and loading procedure used, rate of loading or rate of motion of the crosshead movement, and time to maximum load.
7. The test report shall be permitted to include design values determined in accordance with Section G.

COMMENTARY

(The Commentary is not a part of ANSI/SDI T-CD-2022 Test Standard for Composite Steel Deck-Slabs, but is included for informational purposes only.)

Introduction

The Standard is intended to be complete for normal usage.

The Commentary furnishes background information and references for the benefit of the user seeking further understanding of the basis, derivations and limits of the Standard.

The Standard and Commentary are intended for use by users with demonstrated engineering competence.

Commentary Symbols

The Commentary uses the following symbols in addition to the symbols defined in the Standard. The section number in the right-hand column refers to the Commentary section where the symbol is first used.

Symbol	Definition	Section
b	Unit slab width = 12 in. (1000 mm)	F
d	Effective slab depth, measured from top of slab to the gross section neutral axis of the deck unit, in. (mm)	F
K_{sb}	Shear bond coefficient, psi (MPa)	F
k_1, k_2, k_3, k_4	Shear bond coefficients obtained from multi-linear regression analysis of test data from three or more deck thicknesses tested	F
k_5, k_6	Shear bond coefficients obtained from a linear regression analysis of the test data for each individual deck thickness tested	F
P_t	Ultimate failure load from test, lbs/ft (N/m) of slab width	D2
V_t	Tested shear bond resistance, lbs/ft (N/m) of slab width	D2
W	Weight of the composite slab specimen, lbs/ft (N/m) of slab width	D2
Y_b	Location of the centroid of the deck profile cross section, referenced from the bottom of the deck	F

SECTION B - Test Specimen

B2 Steel Deck Units

B2.3 If the same steel coil is used for more than a single identical set of test specimens, the requirement for a minimum of three steel coupons should be understood that it is not necessary to perform additional coupon tests for additional panels from the same coil.

B3 Dimensions and Construction of Composite Specimens

B3.3 Width

Test specimens of two or more deck unit widths are preferred as representative of actual installation. Test specimens of a single unit width will typically yield lower (conservative) tested capacities.

B3.8 Moving of Test Specimens

It is not advisable to move specimens because moving may damage the specimens, which could result in lower bond strength and lower (conservative) tested capacities. However, in some testing facilities, moving specimens is unavoidable.

SECTION C - Test Configuration

C1 Test Support Frame

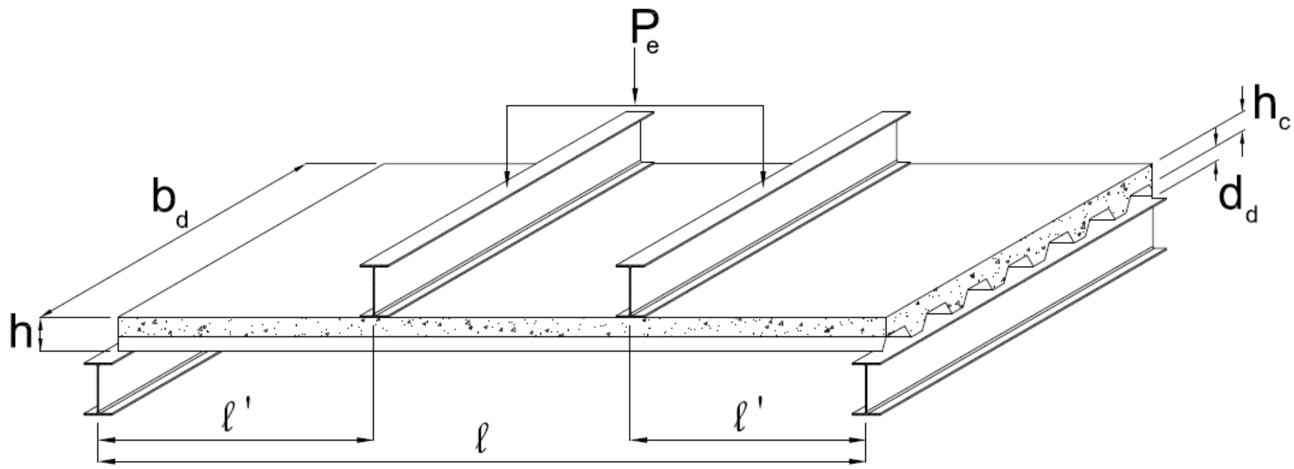

Figure C1.1-1 – Single Span Test Frame

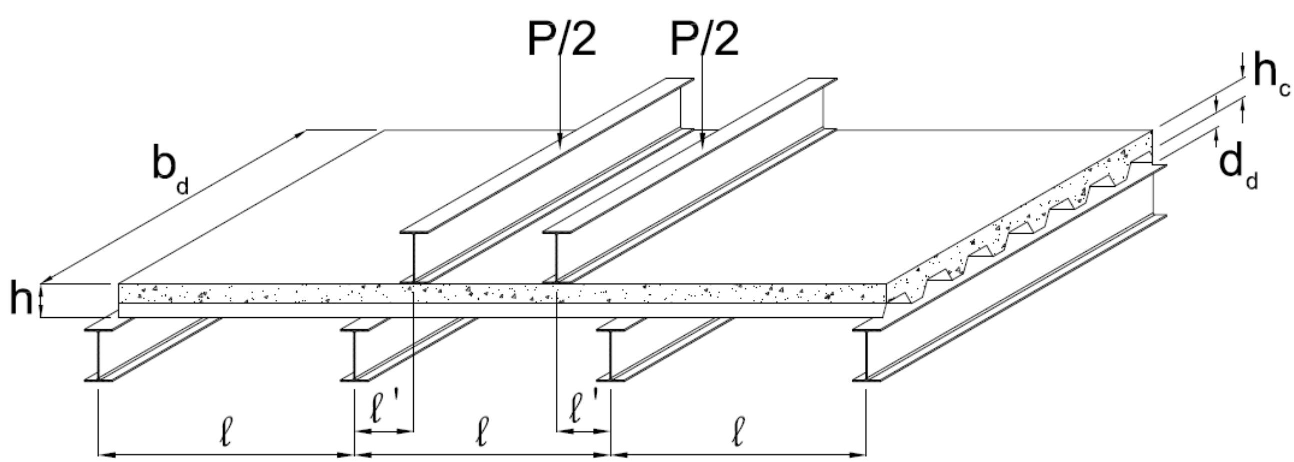

Figure C1.2-1 – Three Span Test Frame (Two Span Similar)

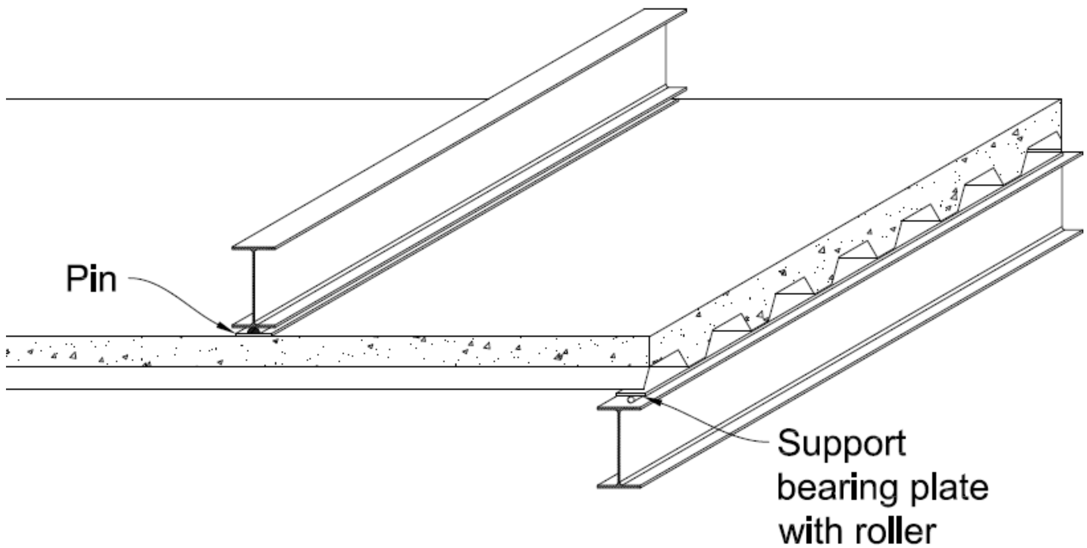

Figure C1.4-1 – Alternate Roller Configuration

SECTION D - Test Procedure

D1 Concrete Strength at Testing

While permitted, it is not advisable to test prior to 28 days if shear bond is anticipated to control the strength. Past experience with tests conducted prior to specimens being cured 28 days, but above nominal concrete strength, have had noticeable moisture at the concrete to steel deck interface. This can negatively impact shear bond strength.

D2 Application of Load

When two concentrated line loads that are symmetric to the span centerline are used for loading the test specimen, the following rational, engineering mechanics equation should be used for calculating the tested shear bond resistance.

$$V_t = P_t/2 + W/2 \qquad \text{(Eq. D2-1)}$$

Where:
V_t = tested shear bond resistance, lbs/ft (N/m) of slab width
P_t = ultimate failure load from test, lbs/ft (N/m) of slab width
W = weight of the composite slab specimen, lbs/ft (N/m) of slab width

When a uniform load is used instead of concentrated loads, Figure D2-1 illustrates the location of the first vertical flexural crack, and the location of the shear span, *l*'.

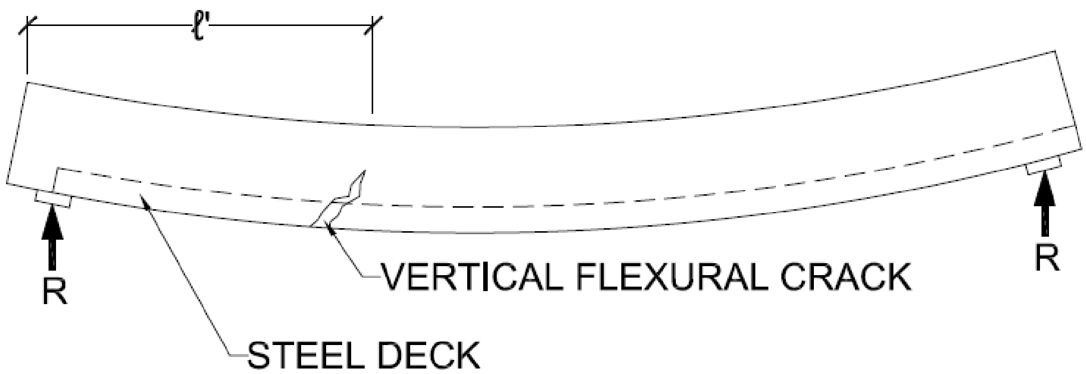

Figure D2-1 – Vertical Flexural Crack

D3 Loading

The anticipated ultimate load may be estimated by calculation, or from test experience of similar profiles. The load should generally be applied in increments of approximately one-tenth of the estimated ultimate load. The rate of loading should also receive proper consideration, since rapid loading may unduly affect the results. A small preload to set bearing, load apparatus, and instrumentation may be desirable, after which the loading sequence is commenced from zero load.

SECTION E - Evaluation of Strength of a Single Composite Deck-Slab Configuration

The method contained in this section of the Standard is modified from AISI S100, Section K2.1.1(a) to be applicable for testing of composite deck-slabs.

SECTION F - Evaluation of Strength of a Composite Deck-Slab System by Confirmatory Testing

Testing under this Section can be used to develop shear bond strength to be used in SDI SD Section F3.2.2.

The method contained in this section of the Standard is modified from AISI S100, Section K2.1.1(b) to be applicable for testing of composite deck-slabs.

The goal of testing of prototypical deck-slab systems is to develop or confirm an analytical model that predicts the available strength over a range of deck profiles, deck thicknesses, slab depths, and concrete types. Various models are acceptable, provided that the essential variables are contained within the test program.

When testing in accordance with SDI T-CD Section F is conducted, the following list of variables should be considered when constructing a test matrix.

1. Steel deck geometry; profile shape and/or embossments
2. Steel deck finish
3. Steel deck base steel thickness
4. Steel deck yield strength
5. Concrete thickness
6. Concrete unit weight
7. Concrete compressive strength
8. Concrete density (normal weight or lightweight)
9. Steel deck-slab span (support spacing)

Experience and judgment should be used in determining which variables should be varied, and which may be held constant. Since extrapolation beyond the limits of the testing is not permitted, care should be exercised in developing the test matrix. It is prudent to work with the approval authority when developing the scope of testing.

The minimum of 3 tests is applied to the entire matrix, not to each individual *configuration*. Therefore, a single test of a *configuration* is sufficient, as long as the total number of tests in the matrix is not less than 3.

A few general observations may be used to reduce the test matrix.

1. Shear bond coefficients may be established using the deck surface coating demonstrating the lowest shear bond strength, provided that verification of a coating's lower shear bond strength is found from comparison test(s). Reported testing has shown that bare steel surfaces perform better than galvanized surfaces, therefore testing performed on galvanized surfaces can usually be conservatively applied to bare steel surfaces.
2. Tests using specimens made of structural lightweight concrete may be used to establish values for normal weight concrete provided that comparison test(s) indicate that the shear bond strength is lower for the structural lightweight concrete.
3. The shear span controls the shear bond resistance for any given deck thickness. The shear span may be varied to achieve the maximum and minimum shear bond resistances of any composite slab system.

4. Results for thinner base steel thickness may conservatively be applied to thicker base steel thickness.
5. Results for steel with lower yield strength may conservatively be applied to higher yield strength steel.

Developing the Analytical Shear Bond Model

Most shear bond models are of the following basic design:

V_t = $bd\ K_{sb}$

Where:
V_t = tested shear bond resistance, lbs/ft (N/m) of slab width
b = unit slab width = 12 in. (1000 mm)
d = effective slab depth, measured from top of slab to the gross section neutral axis of the deck unit, in. (mm)
K_{sb} = Shear bond coefficient, psi (MPa)

The shear bond coefficient, K_{sb}, is developed by modeling (usually a regression analysis, although other methods are acceptable) the test data over a range of variables selected.

Two generally accepted regression models are presented here. These models were developed by Seleim and Schuster (1985) and forms the basis of the Canadian procedures for composite steel deck-slab design (CSSBI-S2-2008). The reader is referred to these documents for more information and a derivation of the regression equations.

Multi-Linear Regression Model When Evaluating Shear Bond for Three or More Deck Thicknesses

When three or more different deck thicknesses are tested, the following equation may be used:

V_t = $bd\ [k_1 t/l' + k_2/l' + k_3 t + k_4]$

Where:
V_t = tested shear bond resistance, lbs/ft (N/m) of slab width
b = unit slab width = 12 in. (1000 mm)
d = effective slab depth, measured from top of slab to the gross section neutral axis of the deck unit, in. (mm)
l' = shear span, in. (mm)
t = base metal thickness, in. (mm)
k_1, k_2, k_3, k_4 = shear bond coefficients obtained from multi-linear regression analysis of test data from three or more deck thicknesses tested

A multiple-linear regression analysis shall be used to determine the shear bond coefficients, k_1, k_2, k_3, and k_4. A comparison of the experimental and computed shear bond resistances is to be made for all the test data. If their ratios are less than 0.85, the shear bond coefficients,

k_1, k_2, k_3, and k_4, should be reduced by 5%. This reduction is necessary because the calibrated resistance factor, ϕ_v, is based on a maximum scatter limit of 15%.

Example of Multi-Linear Regression for Four Deck Thicknesses

The coefficients k_1 through k_4 must be evaluated for each product type only, regardless of the variation in deck thickness and slab depth, by using a multilinear regression analysis. Experimental data is needed for the multilinear regression analysis. The number of tests depends mainly on the level of accuracy required of the computed ultimate shear bond values. In order to obtain a level of accuracy of +- 15% between computed and experimental ultimate shear bond values, Seleim and Schuster (1985) recommend using a minimum of eight data points (experiments) representing three or more different deck thicknesses for a single product type (deck profile).

Example:

For a single product type, the following tested results were obtained:

Test	t (deck) in	Y_b (deck centroid) in	h (slab) in	l' in	Slab Width in	Failure Load #/in	Slab Weight #/in	V_t #/in
A	0.0299	0.8709	3.50	39.37	35.43	139.13	22.20	80.67
B	0.0299	0.8709	6.85	11.81	35.43	1002.45	48.51	525.48
C	0.0358	0.8744	3.50	39.37	35.43	141.11	22.20	81.66
D	0.0358	0.8744	6.81	11.81	35.43	987.78	48.10	517.94
E	0.0480	0.8815	3.50	39.37	35.43	234.24	22.20	128.22
F	0.0480	0.8815	6.97	11.81	35.43	1332.93	49.34	691.13
G	0.0598	0.8886	3.54	39.37	35.43	293.51	22.48	157.99
H	0.0598	0.8886	6.85	11.81	35.43	1409.41	48.51	728.96

Where:

Y_b = location of the centroid of the deck profile cross section, referenced from the bottom of the deck

h = overall thickness of the slab, measured from the bottom of the deck to the top of the concrete

l' = shear span.

d = h - Y_b

Failure Load = the tested failure load, reported in lbs/in. of slab width.

V_t = the tested end shear, calculated as the Failure Load minus the Slab Weight, reported in lbs/in. of slab width

The data is rearranged as follows to allow for the multilinear regression analysis:

Test	b in	d in	Vt/(bd) y	t/L' x1	1/L' x2	t x3
A	12.00	2.63	2.55	0.000760	0.025400	0.0299
B	12.00	5.98	7.32	0.002533	0.084667	0.0299
C	12.00	2.63	2.59	0.000910	0.025400	0.0358
D	12.00	5.94	7.27	0.003033	0.084667	0.0358
E	12.00	2.62	4.07	0.001220	0.025400	0.0480
F	12.00	6.09	9.46	0.004067	0.084667	0.0480
G	12.00	2.65	4.96	0.001520	0.025400	0.0598
H	12.00	5.96	10.19	0.005067	0.084667	0.0598

A multilinear regression analysis is performed using a commercial spreadsheet software package, resulting in the following constants:

k1	351.9604482
k2	69.38377236
k3	78.33614666
k4	-2.006928773
Standard Error of Y Estimate	0.384424064
R Squared	0.990340056
Number of Observations	8
Degrees of Freedom	4

Therefore, the predicted shear bond equation may be written as follows:

$$V_u = \frac{P_u}{2} = bd\left[351.960\frac{t}{l'} + 69.384\frac{1}{l'} + 78.336t + (-2.007)\right]$$

The calculated predicted shear value can then be compared to the tested value results in the following:

Test	V from Prediction Equation	Theory/Test
A	74.78	0.927
B	509.68	0.970
C	90.95	1.114
D	551.51	1.065
E	124.22	0.969
F	661.89	0.958
G	158.59	1.004
H	739.65	1.015

It is seen that the maximum deviation from the tested results is 11.4%, which is less than 15%. Therefore the values of the constants need not be reduced.

Linear Regression Model When Evaluating Shear Bond for One or More Deck Thicknesses

When one or more deck thicknesses are tested, the following equation may be applied:

V_t = bd $[k_5/l' + k_6]$

Where:

k_5, k_6 = shear bond coefficients obtained from a linear regression analysis of the test data for each individual deck thickness tested

A linear regression analysis should be used to determine the shear bond coefficients k_5 and k_6 for each deck thickness. If the ratios of experimental to computed shear bond resistances are less than 0.85, the shear bond coefficients k_5 and k_6 should be reduced by 5%.

Example of Linear Regression for Two Deck Thicknesses

The coefficients k_5 and k_6 must be evaluated for each product type only, regardless of the variation in deck thickness and slab depth, by using a linear regression analysis. In order to obtain a level of accuracy of +- 15% between computed and experimental ultimate shear bond values, Seleim and Schuster (1985) recommend using a minimum of four data points (experiments) representing one or two different deck thicknesses for a single product type (deck profile).

Example:

For a single product type, the following tested results were obtained:

Test	t (deck) in	Yb (deck centroid) in	H (slab) in	L' in	Slab Width in	Failure Load #/in	Slab Weight #/in	Vt #/in
A	0.0299	0.8709	3.50	39.37	35.43	139.13	22.20	80.67
B	0.0299	0.8709	6.85	11.81	35.43	1002.45	48.51	525.48
C	0.0358	0.8744	3.50	39.37	35.43	141.11	22.20	81.66
D	0.0358	0.8744	6.81	11.81	35.43	987.78	48.10	517.94

The data is rearranged as follows to allow for the linear regression analysis:

Test	b in	d in	Vt/(bd) y	1/L' X1
A	12.00	2.63	2.553015	0.025400
B	12.00	5.98	7.323349	0.084667
C	12.00	2.63	2.587762	0.025400
D	12.00	5.94	7.270402	0.084667

A linear regression analysis is performed using a commercial spreadsheet software package, resulting in the following constants:

	k5	79.74949549
	k6	0.544751597
Standard Error of Y Estimate		0.031664862
R Squared		0.999910243
Number of Observations		4
Degrees of Freedom		2

Therefore, the predicted shear bond equation may be written as follows:

$$V_u = \frac{P_u}{2} = bd\left[79.749\frac{1}{l'} + 0.544\right]$$

The calculated predicted shear value can then be compared to the tested value results in the following:

Test	V from Prediction Equation	Theory/Test
A	81.22	1.007
B	523.58	0.996
C	81.11	0.993
D	519.82	1.004

It is seen that the maximum deviation from the tested results is 0.7%, which is less than 15%. Therefore the values of the constants need not be reduced.

Alternate Shear Bond Analysis

Alternate rational methods for establishing the shear bond strength are permitted to be used if the pertinent parameters contributing to a shear bond failure, including deck cross section, steel thickness, shear span, concrete weight, strength, and type, shear transfer devices, and method of loading, are appropriately considered. These methods may include linear and nonlinear relationships between the parameters. The methods contained in ASCE 3-91 should be considered to be an acceptable alternate method.

References

1. American Society of Civil Engineers (ASCE). *Standard for the Structural Design of Composite Slabs*, ANSI/ASCE 3-91. Reston, VA, 1991.
2. Canadian Sheet Steel Building Institute (CSSBI). *Criteria for the Testing of Composite Slabs*, CSSBI S2-2017. Cambridge, Ont., 2017.
3. Seleim, S.S. and Schuster, R.M, "Shear-bond resistance of composite deck-slabs." Canadian Journal of Civil Engineering, Vol. 12, pp. 316-324. 1985.