AMERICAN NATIONAL STANDARDS INSTITUTE/ STEEL DECK INSTITUTE

ANSI/SDI AISI S923-2024

Test Standard for Determining the Strength and Stiffness of Shear Connections in Composite Members

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2024 Edition

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First Printing, December 2024

PREFACE

(This Preface is not part of the ANSI/SDI AISI S923-2024, *Test Standard for Determining the Strength and Stiffness of Shear Connections in Composite Members*, but is included for informational purposes only.)

This Standard is a revision of ANSI/AISI S923-2020.

This Standard has been developed as a consensus document for the design of cold-formed steel members and structures. The intention is to provide criteria for routine use and not to provide specific criteria for infrequently encountered problems, which occur in the full range of structural design. The Symbols and Appendices 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 may be 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.

ANSI/SDI AISI S923-2024
TEST STANDARD FOR DETERMINING THE STRENGTH AND STIFFNESS OF SHEAR CONNECTIONS IN COMPOSITE MEMBERS

1. Scope

This *Standard* provides a method for determining the strength and stiffness of *composite shear connections* used for shear transfer at the interface of a concrete slab or concrete-filled steel deck with a *supporting steel member*.

This *Standard* is composed of Sections 1 through 10 inclusive.

2. Referenced Documents

The following documents or portions thereof are referenced within this *Standard* and shall be considered as part of the requirements of this document.

a. American Concrete Institute (ACI), Farmington Hills, MI:

ACI 318-22, Building Code Requirements for Structural Concrete

b. ASTM International (ASTM), West Conshohocken, PA:

A90/A90M-21, *Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles With Zinc or Zinc-Alloy Coatings*

A123/A123M-17, *Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*

A370-24, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

C31/C31M-24a, *Standard Practice for Making and Curing Concrete Test Specimens in the Field*

C39/C39M-23, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*

C138/C138M-23, *Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete*

E6-23a, *Standard Terminology Relating to Methods of Mechanical Testing*

IEEE/ASTM SI10-16, *American National Standard for Metric Practice*

c. Steel Deck Institute, P.O. Box 70, Florence, South Carolina 29503:

ANSI/SDI AISI S100-2024, *North American Specification for the Design of Cold-Formed Steel Structural Members*

3. Terminology

Where the following terms appear in this *Standard*, they shall have the meaning as defined herein. Terms not defined in Section 3 of this *Standard*, ANSI/SDI AISI S100, or ASTM E6 shall have the ordinary accepted meaning for the context for which they are intended.

Base Steel. The top chord, flange, or horizontal surface of a *supporting steel member*, or steel deck, to which the *shear connection* is made.

Base Steel Thickness. The thickness of the *base steel*, exclusive of all coatings and galvanization.

Cold-Formed Steel Shear Tab (*Connector*). A *shear connector* mechanically cut and formed from cold-formed *base steel* resulting in an embedded steel element of a *composite shear connection* or a tension interface connection.

Composite Shear Connection. Structural elements, or means, which fully or partially integrate the concrete slab and the supporting steel into a single structural element at the interface of the concrete slab and the supporting steel member. The connection strength, stiffness and *slip capacity* are determined from the mechanical and geometric properties of the elements and the structural interaction among each element.

Shear Connector. Device that is used to transfer the shear force between concrete slab or concrete-filled deck and the *base steel*.

Slip Capacity. The deflection of the *composite shear connection*, measured at a post-peak strength level.

Steel Deck Profile. A specific configuration of formed steel deck geometry, including nominal deck height, nominal sheet steel base metal thickness, nominal flange widths, nominal web angles, and nominal bend radii.

Steel-Headed Stud Anchors. A s*hear connector* consisting of steel shank and enlarged head welded to the *base steel*.

Stiffness. Resistance of the *composite shear connection* to slip, taken as the ratio of the applied force to the corresponding deflection.

Stiffness, Elastic. Stiffness measured at an applied force below the proportional limit.

Supporting Steel Member. An element comprised of *base steel* and other components. Examples include structural steel beams and columns, steel joists, and cold-formed steel framing.

4. Units of Symbols and Terms

Any compatible system of measurement units shall be permitted to be used in this *Standard*, except where explicitly stated otherwise. The unit systems considered in this *Standard* shall include U.S. Customary units (force in kips and length in inches) and SI units (force in Newtons and length in millimeters) in accordance with IEEE/ASTM SI10.

5. Measurement Precision

5.1 Loads shall be recorded to a precision of ±1 percent of the full range of the measuring device.

5.2 The accuracy of the load-measuring equipment shall be ±1 percent of the anticipated peak load.

> **User Note:**
> The capacity (range) of the load-measuring device should be appropriate to the expected maximum tested load. The use of a measuring device with a calibrated capacity greatly exceeding the anticipated load is inappropriate. A target ratio of the load-measuring device capacity to specimen strength of no greater than three is recommended.
>
> The tests should be conducted on a testing machine that complies with the requirements of ASTM E4-21, *Standard Practices for Force Verification of Testing Machines*.

5.3 Deflections shall be recorded to a precision of 0.01 in. (0.25 mm).

5.4 Devices used to measure loads and deflection shall be maintained in good operating order, used only in the proper range, and calibrated periodically.

5.5 Calibration readings taken over the full range anticipated in the test shall be accurate to no less than the precision requirements for the device given in Sections 5.1 and 5.3.

6. Test Fixture

A test setup is illustrated in Figures 6-1(a) and 6-1(b). A minimum of two (2) slip measuring devices shall be placed on each concrete panel and distributed equally on either side of the steel member assembly, for a total of four (4) minimum. The actual test setup shall be representative of the intended use in the installed application.

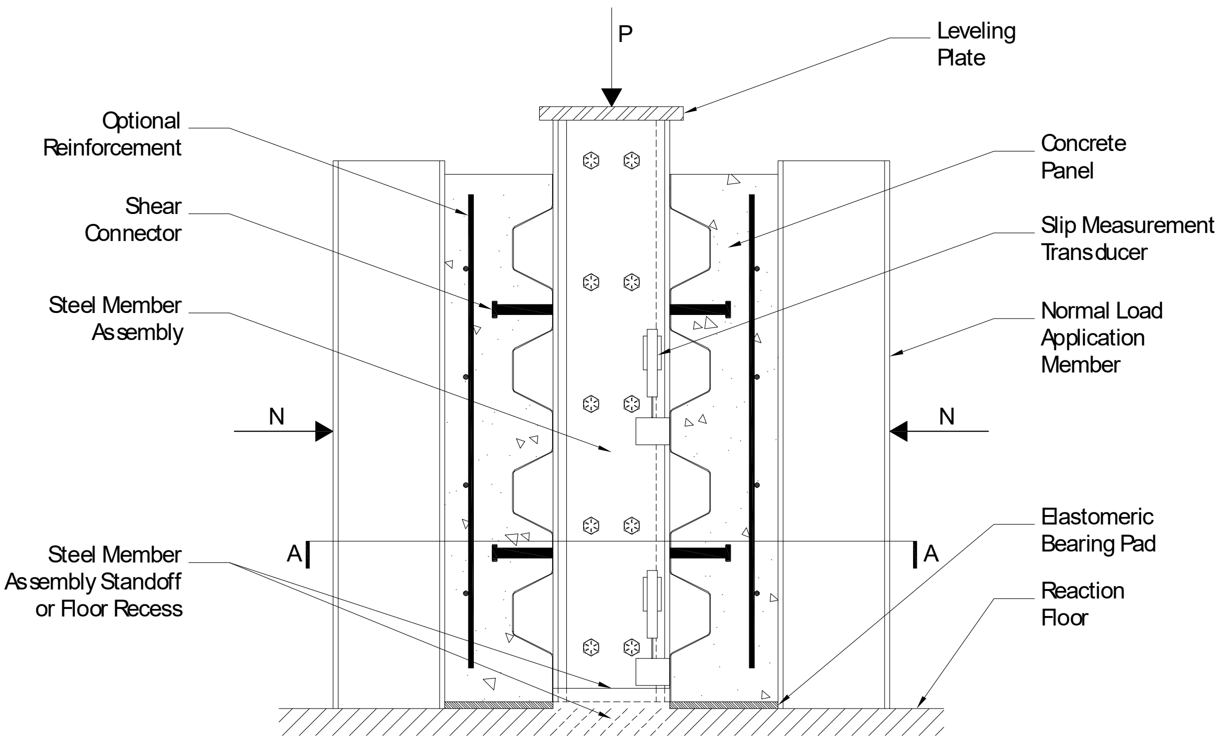

Figure 6-1(a) Test Setup Side View

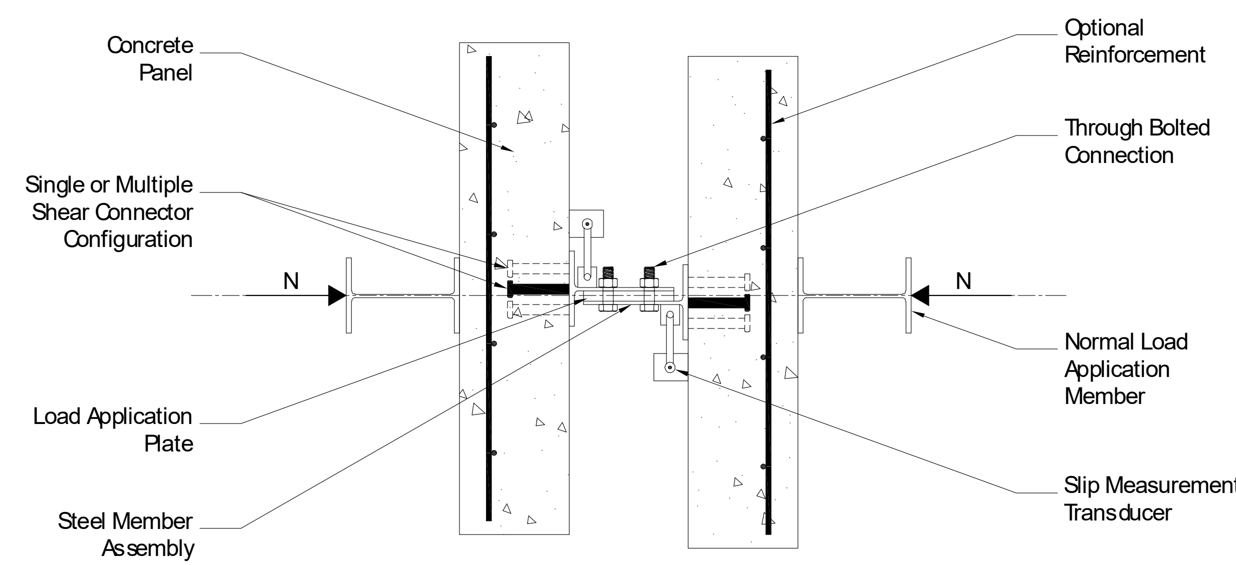

Figure 6-1(b) Test Setup Top View (Section A-A)

7. Test Specimen

7.1 The number of specimens tested shall comply with the requirements of Section K2.1.1 of ANSI/SDI AISI S100. A test plan documenting the test materials, test configuration, and test procedure shall be prepared.

7.2 Dimensions. The concrete slabs and supporting steel members shall be suitably dimensioned to accommodate the composite shear connection. Attention shall be given to:

7.2.1 The test specimen length, considering the longitudinal spacing of the connectors.

7.2.2 The test specimen width, considering the effective width of the composite shear connection.

7.2.3 The concrete slab thickness, considering the minimum thickness of the slab to permit the embedment of the shear connectors.

7.3 Shear Connection. All pertinent dimensions, such as length, width, thickness, shear connection spacing, and radius of bent components, shall be measured on each unique configuration. A minimum number of shear connectors and the position of the shear connectors relative to the steel deck, as applicable, shall be tested in accordance with the applicable building code or manufacturer's instructions.

7.4 Base Steel. The selection and the configuration of the *base steel* shall be consistent with the intended application. Testing of *base steel*, whether or not as an integral part of the connector, such as coupons of a structural steel top flange, steel joist top chord or cold-formed steel member flange, shall be conducted to ensure compliance with the material standard specified. Material test reports from the manufacturer of the heat of steel utilized to produce the *base steel* are an acceptable alternative, provided traceability to steel member production is verified. The steel yield strength, tensile strength, and elongation shall be determined in accordance with ASTM A370. The dimensions of the supporting steel, including *base steel thickness*, shall be measured.

7.5 Steel Deck. When steel deck is used in any particular configuration, for each *steel deck profile*, geometrical dimensions such as coated steel thickness, *base steel thickness*, depth of the *steel deck profile*, top flange width, web width, web angle, bottom flange width, and average concrete rib width shall be measured. The decks are permitted to be oriented either longitudinally or transversely to the row of *shear connectors*, as set forth in the applicable building code or manufacturer's instructions.

7.6 Concrete. Concrete materials, mixtures, and proportions shall conform to the requirements of ACI 318.

7.6.1 Compressive strength tests shall be the average of the strengths of at least three cylinders made from the same sample of concrete. Strength tests shall be performed in accordance with ASTM C39/C39M and the average compressive strength reported. Concrete sampling, cylinder preparation, and curing shall comply with ASTM C31/C31M. Both standard curing and field curing in accordance with ASTM C31/C31M are permitted. Each configuration of replicate test specimens shall be specific to a single nominal concrete weight (i.e., normalweight, lightweight, or sand-lightweight) and the concrete weight shall be determined as defined in accordance with ASTM C138/C138M and recorded. The compressive strength shall be established by either: 1. Interpolation of strength tests conducted at the beginning and end of the *composite shear connection* testing, with a maximum seven-day interval between the cylinder tests; or 2. Strength versus age relationships developed using cylinder tests of the concrete used in the test members at various test ages.

7.6.2 For field curing, all test specimens and concrete cylinders shall be stored and cured in a nominally identical manner.

7.7 Concrete Reinforcement. The concrete slabs may be reinforced or unreinforced. Welded wire reinforcement (WWR) or deformed reinforcing bar materials properties and testing shall conform to ACI 318. Reinforcement placement, when used, shall comply with either Section 7.7.1 or 7.7.2.

7.7.1 If used to preclude longitudinal slab splitting or slab buckling in the test specimen, or for providing integrity when moving the test specimen, reinforcement shall be placed outside the zone where connection capacity may be influenced, below the surface of the test member. Reinforcement shall not be placed between shear connectors and test member edge in the direction of loading.

7.7.2 If intended as part of specified shear connection assembly, it is permitted that reinforcement be placed as specified.

8. Test Procedures

8.1 Concrete slabs shall be cast in the horizontal position to ensure the concrete is properly cured and bonds to the surface of the embedded connector. Vertical casting is permitted where the actual end use application depends on this position, such as for cast-in-place walls. Proper consolidation of concrete shall be achieved, and the casting shall be in such a fashion that would not alter the performance of the shear connection compared to expected end use.

8.2 When steel deck is used in test specimens, there shall be no additional fastening of the steel deck panel to the *supporting steel members* of the test assemblies other than the *shear connectors*. However, where the steel deck is an integral element of the shear transfer mechanism, additional fastenings to the *supporting steel members* are permitted to complete the load path.

8.3 Test Specimen. To assure the two concrete slabs have uniform bearing pressure across their entire edge surface area in contact with the floor, an elastomeric bearing pad shall be placed under each test specimen.

> **User Note:**
> The *supporting steel member(s)* used in the test assembly may be structural steel or cold-formed steel, depending on the intended connection with the *shear connector*. The two halves of the test specimen will be bolted together through the steel test member assembly.

8.4 Load Application

8.4.1 Initial Loading. A steel loading plate of adequate size shall be placed over the steel member. Axial load shall be applied through the steel leveling plate to the steel member, which induces shear force at the interface between concrete and the steel member in such a manner that the load is equally applied to both halves of the test specimen. Confirmation that an equal load is being applied to both halves of the test specimen is achieved by comparing the slip measurements along each half of the specimen during the load application. If a deviation in slip exceeding 15 percent from one side to the other occurs before reaching 10 percent of the expected peak load, the test specimen shall be unloaded and the centering of the loading apparatus checked and realigned as necessary.

8.4.2 Normal Load. A normal load, perpendicular to the axial load direction is permitted to be applied concurrently to the surface of the two concrete elements. The normal load during the axial load application is permitted to 1) be fixed load at a level less than or equal to 10 percent of the maximum anticipated axial load or 2) increase proportionally to the axial load, limited to 10 percent or less of the axial load at any given time.

8.4.3 Axial Load. The axial force is induced in two phases, load control and displacement control.

8.4.3.1 Load Control. Under the first phase, load control, the axial load shall be applied in increments equal to approximately 5% of the expected peak capacity of the specimen, but shall not exceed 2000 lbs (8,896 N.) Axial and normal load shall be applied under load control until a load of approximately 80 percent of the expected peak capacity is reached.

8.4.3.2 Displacement Control. After loading attains 80 percent of the expected peak capacity, displacement control shall be utilized where loading is applied until slip increases by a fixed increment. During the displacement control phase, the load shall be applied such that the average slip increment does not exceed 0.05 inch (1.27 mm). The longitudinal slip between each concrete element and the steel section shall be measured continuously during loading or at each load increment. The load and slip shall be measured at least until the load has dropped to 20 percent below the peak load.

8.4.4 Configurations. Representative test specimen configurations are illustrated in Figure 6-1. The level of detail given in Figure 6-1 of this *Standard* shall be included in each test report. For cold-formed steel studs, the specimen is permitted to be configured in a single or a double-stud configuration, as applicable. For double-stud configurations, the pattern of adjacent connectors shall comply with the manufacturer's instructions (in-line, alternating, etc.).

8.4.5 Slip Measurement. The slip measuring devices described in Section 6 and positioned as illustrated in Figure 6-1 shall be used to measure the slip of the *composite shear connection* from the initiation of load application. These devices shall be located to minimize any deformation not associated with connection slip. The measurements from these devices shall be averaged to represent the slip of the connection. Slip readings shall be taken at sufficiently frequent load intervals to permit establishment of a satisfactory load-displacement curve based on the average of the four connection slip measurements. The general behavior of the *composite shear connection* under load shall be observed and recorded including the peak load, the first abrupt decrease in load, the *slip capacity* load, the failure mode, the ultimate load, and other significant details. Slip measurements influenced by concrete breakout at the *shear connectors* shall not be used for *slip capacity* determinations.

9. Data Evaluation

9.1 General. Evaluation of the test results and the determination of the available strength (i.e., allowable strength and/or design strength [resistance]), if required, shall be conducted in accordance with the procedures described in Section K2.1 of ANSI/SDI AISI S100.

9.2 Slip Capacity. The *slip capacity* shall be measured at the designated post-peak strength from the load-versus-slip relationship. The average of slip measurements shall be used to establish the load-versus-slip relationship (See Figure 9.2).

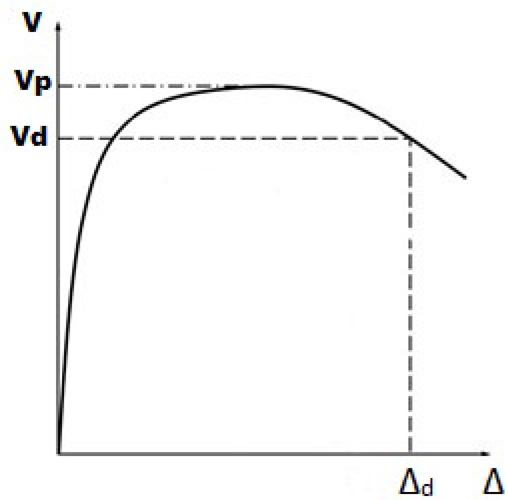

Figure 9.2 Slip Capacity Determination

where V = Test load, V_p = Peak load, V_d = Test load specified for *slip capacity* measurement, Δ = Slip at a load of V, and Δ_d = Slip at a load of V_d.

9.3 Stiffness.

9.3.1 The slip used for stiffness determinations shall be the average of all slip measuring devices for the shear load under consideration.

9.3.2 Secant Stiffness. The secant *stiffness*, k_s, shall be calculated from Eq. 9.3-1:

$$k_s = V / \Delta \qquad (Eq.\ 9.3\text{-}1)$$

where
V = Shear load under consideration
Δ = Slip taken from the test results, at a load of V

9.3.3 Chord Stiffness. The chord *stiffness*, k_{ch}, is the slope of the load-deflection curve between two load slip levels on the curve, calculated from Eq. 9.3-2:

$$k_{ch} = \frac{V_2 - V_1}{\Delta_2 - \Delta_1} \qquad (Eq.\ 9.3\text{-}2)$$

where
V_1 = Load at Point 1, measured from the test
V_2 = Load at Point 2, measured from the test
Δ_1 = Slip taken from the test results, at a load of V_1
Δ_2 = Slip taken from the test results, at a load of V_2

9.3.4 Elastic Stiffness. The elastic *stiffness*, k_e, is determined as the slope of a straight line fitted to the initial linear portion of the load-slip curve measured at predetermined loads or slips on the curve. Either secant *stiffness*, k_s, or chord *stiffness*, k_{ch}, is permitted.

The average of k_e taken from the number of tests specified in Section 7.1 is permitted to be used to represent the performance of the tested configuration.

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

10. Test Report

10.1 The test report shall include a description of the tested specimens, including a drawing detailing all pertinent dimensions.

10.2 The test report shall include the measured steel mechanical properties of the tested specimen, and concrete strength of the tested cylinders.

10.3 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 6 and 8. Additionally, photographs shall supplement the detailed drawings of the test setup.

10.4 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.

10.5 The test report shall include individual load-versus-slip values and curves, as plotted directly, or as reprinted from data acquisition systems.

10.6 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 test specimen tested, and a description of the general behavior of the test specimen during load application. Additionally, photographs shall supplement the description of the failure mode(s).

10.7 The test report shall include *slip capacity* and *stiffness* values determined in accordance with Sections 9.2 and 9.3, respectively, when specified, for the load levels under consideration.

SDI AISI S923-C-2024
COMMENTARY ON TEST STANDARD FOR DETERMINING THE STRENGTH AND STIFFNESS OF SHEAR CONNECTIONS IN COMPOSITE MEMBERS

1. Scope

Shear connectors, as defined in this *Standard*, transfer shear forces between concrete and steel elements. Available types include welded steel headed stud anchors, channel clips, anchor bolts, dowel bars, self-drilling stand-off screws, mechanically attached studs, mechanically attached cold-formed steel clips, and *cold-formed steel shear tabs*. Their most common application is to develop full or partial composite action by limiting the slip between the steel and concrete components. These devices are selected for their ability to transfer force, their *stiffness*, and their ability to accommodate slip between *the base steel* and concrete or concrete-filled *steel deck profile*. Investigations to verify their performance found that their capacities cannot be verified by flexural tests. This *Standard* provides procedures to directly test *composite shear connections* in shear and reports the resulting strength, slip, and *stiffness*.

"Push-out Tests" of the type in this *Standard* were originally developed in the 1930s. This test captures the load-slip performance of *composite shear connections*.

This test *Standard* may need to be augmented for testing shear connections used with bridges, due to the need to investigate the effects of moving loads. High-cycle fatigue testing is typically conducted for such applications.

Innovations and research in composite construction with structural steel or cold-formed steel and concrete resulted in geometries and connection methods that do not lend themselves to analytical methods to assess strength and deflection capacities. Tests of *composite shear connections* in accordance with this *Standard* provide values for assessment and application in ANSI/SDI AISI S100 and ANSI/AISC 360 (2022).

3. Terminology

The terms provide descriptions of the *composite shear connection*, including *shear connectors* and their types. The descriptions are general, anticipating *composite shear connections* may take many forms.

Examples of *shear connectors* include *steel-headed stud anchors* and *cold-formed steel shear tabs*. The connectors are a part of the shear connection assembly and may be mechanically attached to the composite member components or integrated therewith.

Slip capacity, which is the ability of the *composite shear connection* to deform under load before failure, is sometimes expressed as ductility (ANSI/AISC 360 (2022)). *Composite shear connections* exhibiting a deformation hardening response may be considered ductile by sustaining inelastic or plastic deformations before failure without significant losses in load capacity.

6. Test Fixture

The test fixture figures are representative and may be modified for certain connection assemblies. The fixture must be sufficiently rigid to permit the development of full connection strength. Care should be taken to place the concrete panels to fully bear on the test base. Panel rotation may occur when bearing is not sufficient, which can be verified by observing negative slip measurements during initial loading. Panels may need to be shimmed to permit the connections to be loaded as intended.

7. Test Specimen

7.1 The requirements in Section K2 of ANSI/SDI AISI S100 are applicable to replicate testing of a single configuration. Other configurations may require additional sets of tests.

7.2 Dimensions.

7.2.1 The IAPMO UES EC-023 and EC-033, which are evaluation criteria for specific types of *shear connections,* suggest a specimen length and width of approximately three feet to permit testing of multiple connection points.

7.2.3 Since the concrete is usually cast horizontally and transported to the fixture after curing, the slab thickness and reinforcement need to be adequate to prevent damage before testing.

7.3 Shear Connection. The dimensions of the test specimens should be reviewed for conformance with product drawings. Pertinent materials properties and surface finishes should be documented by tests or certified mill reports.

7.4 Base Steel. Any coatings should be documented by tests or by certified mill reports.

7.5 Steel Deck Profiles. Where the *shear connector* is placed through *steel deck profiles*, the orientation of the deck may influence the capacities attained.

The position of the *shear connector*s within the *steel deck profile* ribs needs to be considered. Connectors centered or located away from the loading direction in the ribs are less likely to exhibit pullout failures, as illustrated in Figure C-7.5-1.

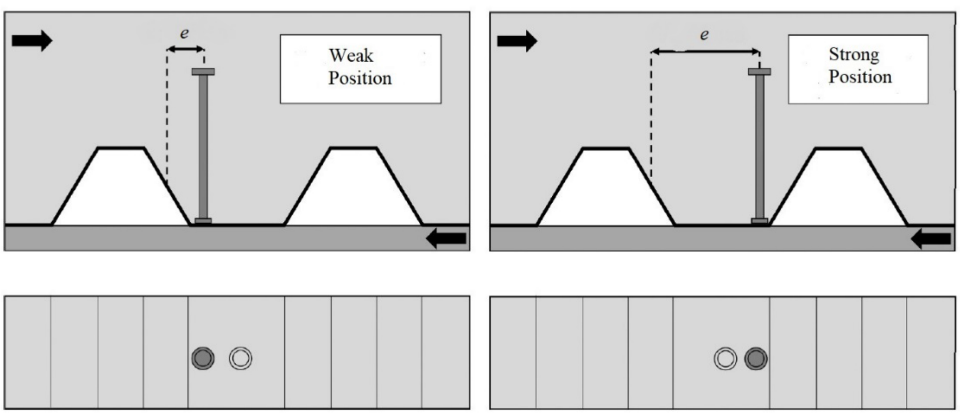

Figure C-7.5-1 Position of Shear Connector in Steel Deck Profile Rib

7.6 Concrete. The concrete unit weight (normalweight, lightweight, all-lightweight), compressive strength, aggregate size, and other characteristics may influence the shear connection capacity. Therefore, tests of concrete with different properties may be appropriate.

7.6.1 Standard cured cylinders are cured at 73 +/- 3°F until the specified age of testing using either water storage tanks saturated with lime or moist cure rooms. Standard curing is expected to result in the concrete reaching or exceeding the specified compressive strength.

7.6.2 Field-cured cylinders are subject to the same temperature and relative humidity conditions that the completed structure will experience in its environment. Field curing is expected to result in concrete compressive strengths closer to that of the test specimens.

7.7 Concrete Reinforcement. Concrete placed over s*teel deck profiles* requires reinforcement. ANSI/AISC 360 (2022) governs the composite design of concrete over *steel deck profiles and* does not acknowledge the contribution of the deck as concrete reinforcement, deferring to ACI 318 for minimum reinforcing. However, ANSI/SDI SD (2022) provides a method where the deck may act as positive reinforcement, while negative reinforcement would need to conform to ACI 318.

7.7.1 Failure of the connection during the test may be due to several modes such as *shear connector* breakage or yielding, the connector pullout from the concrete or *shear connector* breakout of the concrete. The development of a breakout will result in a cone originating from the embedded end of the *shear connector*. Reinforcement can be placed outside the estimated failure plane to avoid influence on the concrete breakout.

8. Test Procedures

8.3 Test Specimen. During test specimen construction, care should be taken to ensure the steel member is installed perpendicular to the bearing edge of the concrete panel to ensure uniform bearing pressure across the edge surface and mitigate panel rotation.

8.4 Load Application

8.4.1 Some earlier tests (Dallam, 1968) reported that misalignment of either the specimens or the loading source could result in unequal distribution of the forces to the *shear connectors*, limiting usability of the test results. This possibility can be remedied if the slip measurements from each device during the initial load phase are compared. Where the slip readings exhibit significant differences from each other, the loading should be halted and the test assembly examined for poor alignment, with adjustments taken to permit an equal distribution of load to the *shear connectors.* The test assembly may then be reloaded and the slip readings reviewed again for consistency.

8.4.2 The normal load magnitude stipulated in Section 8.4.2 can be used to counteract tensile forces induced in the shear connectors during the test, and more closely follow the loading mechanisms of steel-concrete composite members in positive bending. The moment induced by the eccentricity of load application is resisted by tension in the *shear connectors*, which is illustrated in Figure C-8.4.2-1. The degree of tension resistance in the *shear connectors* is affected by the degree of friction between the test member and the supporting floor. The amount of friction will be affected by the location of the bearing pads if used. The normal load is intended to confine the concrete and induce a pure shear mode of failure without the adverse effects of tension or prying due to eccentricities in the test assembly. The normal load limit of 10 percent of the vertical load is intended to minimize the impact of potential additive shear friction on the strength of the connection. Tests with normal loads in the range of 0 to 16 percent of the vertical load were cited by Hicks et al. (2017), and it was concluded that loadings in the range of up to 10 percent of the vertical load exhibited reliable behavior and compared most favorably with companion beam tests. This limit also standardizes the range of normal loads and allows for comparisons of test results between different anchors, configurations of anchors, steel deck profiles, concrete properties, and concrete thickness without bias of significantly different normal loads.

In addition, the type of assembly being tested may influence the decision to apply a normal load. Studies (Hicks et al., 2017) have demonstrated that concrete over *steel deck profile* assemblies exhibit erratic behavior and failures not consistent with practice when the push-out tests were conducted without a normal load applied.

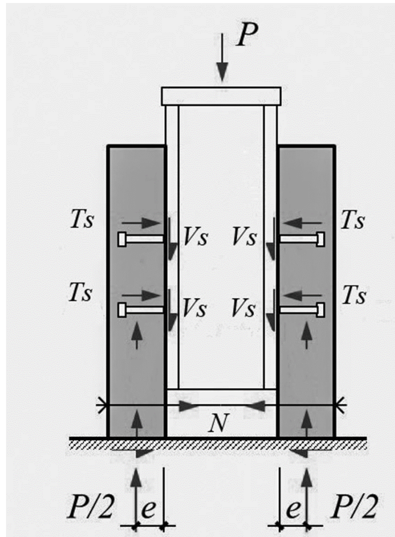

Figure C-8.4.2-1 Tension in Shear Connectors Resist the Moment Induced by Eccentricity

8.4.3 Axial Load. The axial load is applied through load control and displacement control.

8.4.3.1 Load Control. In the load control, the increments of loading are constant, and the load can be held at a constant level for any length of time. One limitation of this procedure is that the test is completed once the peak load is attained as the specimen cannot carry a higher load. Load control is appropriate within the linear elastic range of the load-displacement curve, which is assumed as up to 80 percent of the expected peak strength, above which permanent displacement can occur, from concrete crack propagation or yielding of the *shear connector.* The use of load control allows for the measurement of slip at each interface, which would provide feedback on whether the loading is applied equally to both sides of the specimen (see Figure C-8.4.2-1).

8.4.3.2 Displacement Control. Displacement control is used to measure slip or stiffness decrease. Most likely the test will not fail destructively, as slippage eventually results in decreasing loads. In current design standards (AISC 360 (2022), EN 1994-1-1 (2004)), it is appropriate to observe the load resistance reduction as the base *shear connector* capacity declines while the displacement increases.

8.4.4 Configurations. The test specimen configurations should be reported in detail. It is permitted to use the prototype in the test standard or establish a new prototype.

9. Data Evaluation

9.1 General. Depending on the design requirements, the strength may be determined from the peak load, a reduced load based on the peak load, or a load at a predetermined slip. ANSI/SDI AISI S100 provides a methodology for deriving the design level strengths (ASD or LRFD) from the test results.

As the test method is intended to determine the strength, slip and stiffness of composite shear connections, failure should occur by fracture or dislodgement of the connectors. Other types of failure may be indicative of a deficiency in the design of the test, or the construction of the test panels. For example, slab buckling has occurred in tests of concrete over metal deck panels, which was remedied by the application of the normal load.

This test method will load multiple *composite shear connections* simultaneously and assign individual strengths by dividing the total load by the number of connections. In evaluating the data, a closer examination of the individual connection performance may be needed to assure consistency, such as consistency between the slip readings. Failure may initiate in one *composite shear connection*, which may indicate a deficiency in the connection installation or materials and would skew the assigned capacities downwards.

9.2 Slip Capacity. The *composite shear connections* should possess *slip capacity* to accommodate the horizontal movement occurring between the concrete and the *supporting steel member* as the composite beam is loaded. For a typical uniformly loaded beam, slip is greatest at the end. The slip capacity of the *shear connector* is influenced by the orientation of the *steel deck profile* to the loading direction and the type of loading. The connection *slip capacity* must conform to typical requirements in the design specifications such as ANSI/AISC 360 (2022).

9.3 Stiffness. The *stiffness* of a *composite shear connection* may be computed from either the secant method or the chord method, depending on the specifications. For example, EN 1994-1-1(2004) permits the secant method, measured at 60% of the peak strength. In ANSI/AISC 360 (2022), minimum shear elastic *stiffness* is required to be 2,000 kips/in. Per the commentary of ANSI/AISC 360, shear elastic stiffness is considered as the slope of the straight-line connecting two points on the load-slip curve in a push-out specimen test, corresponding to 10% and 40% of the peak load.

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