AISI S923-20

American Iron and Steel Institute

AISI STANDARD

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

2020 Edition

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Approved by
the AISI Committee on Specifications for the Design of
Cold-Formed Steel Structural Members

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The material contained herein has been developed by the American Iron and Steel Institute Committee on Specifications for the Design of Cold-Formed Steel Structural Members. The organization and the Committee have made a diligent effort to present accurate, reliable, and useful information on testing of cold-formed steel members, components, or structures. The Committee acknowledges and is grateful for the contributions of the numerous researchers, engineers, and others who have contributed to the body of knowledge on the subject. With anticipated improvements in understanding of the behavior of cold-formed steel and the continuing development of new technology, this material will become dated. It is anticipated that future editions of this test procedure will update this material as new information becomes available, but this cannot be guaranteed.

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PREFACE

The American Iron and Steel Institute Committee on Specifications developed this *Standard* to determine the strength and stiffness of shear connections in composite members through testing.

This *Standard* is intended for adoption and use when the strength and stiffness of the shear connections are needed in the design of composite members composed by concrete slabs or concrete-filled deck connected to steel members.

The Committee acknowledges and is grateful for the contribution of the numerous engineers, researchers, producers and others who have contributed to the body of knowledge on this subject. Special thanks are given to Brian Gerber, J.R. Ubejd Mujagic, and members of the Composite Design Subcommittee for drafting and providing inputs to the *Standard*.

Commentaries and User Notes are non-mandatory and copyrightable portions of this *Standard*.

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AISI S923-20
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 the concrete slab or concrete-filled steel deck with the 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 318-19, *Building Code Requirements for Structural Concrete*

b. American Iron and Steel Institute (AISI), Washington, DC:

S100-16 (2020) w/S2-20, *North American Specification for the Design of Cold Formed Steel Structural Members* With Supplement 2

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

A90/A90M-13(2018), *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*

A370-20, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

C31/C31M-19, *Standard Practice for Making and Curing Concrete Test Specimens in the Field*

C39/C39M-18, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*

C138/C138M-17a, *Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete*

E6-15e2, *Standard Terminology Relating to Methods of Mechanical Testing*

IEEE/ASTM SI 10-16, *American National Standard for Metric Practice*

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*, 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*). *Shear connector* mechanically cut and formed from the *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 ductility 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*.

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

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. *Shear connector* consisting of steel shank and enlarged head welded to the *base steel*.

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 SI 10.

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 E4-20, *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

The test setup is illustrated in Figures 6.1-1(a) to 6.1-1(e).

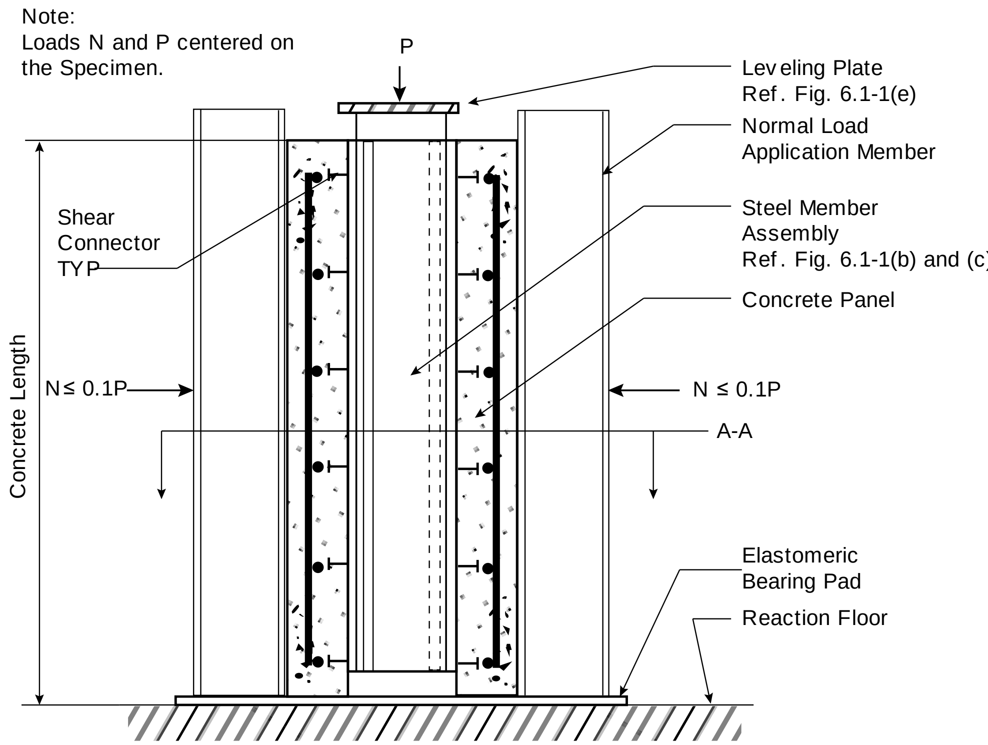

Figure 6.1-1(a) Test Setup

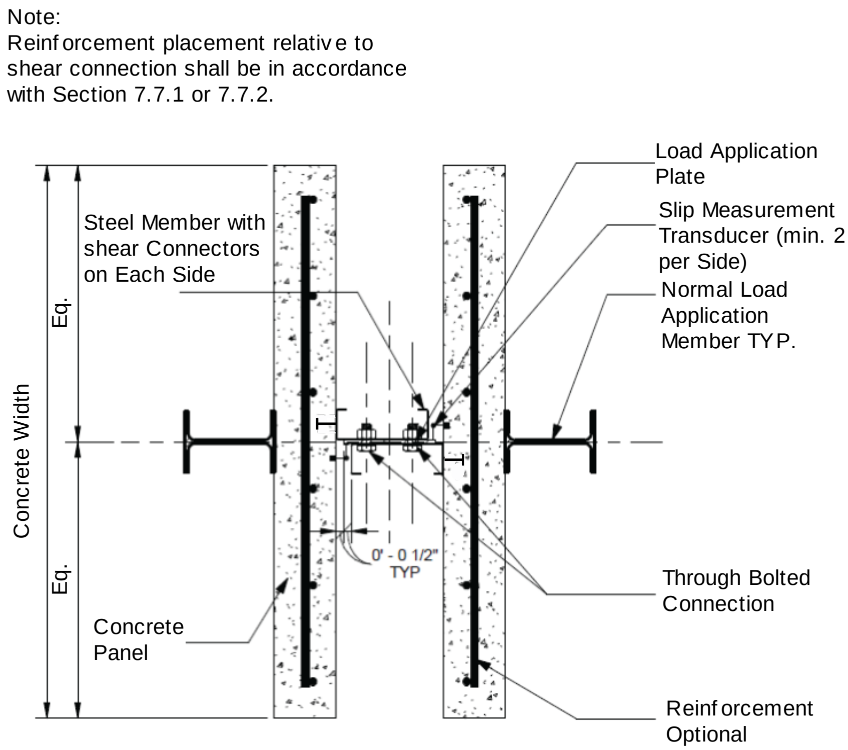

Figure 6.1-1(b) Single Shear Connector Configuration (Section A-A)

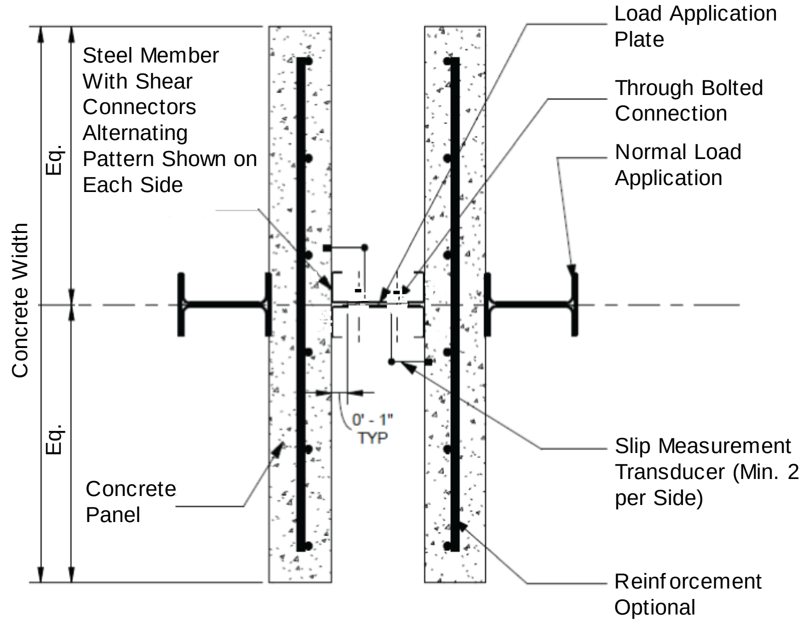

Figure 6.1-1(c) Double Shear Connector Configuration (Section A-A)

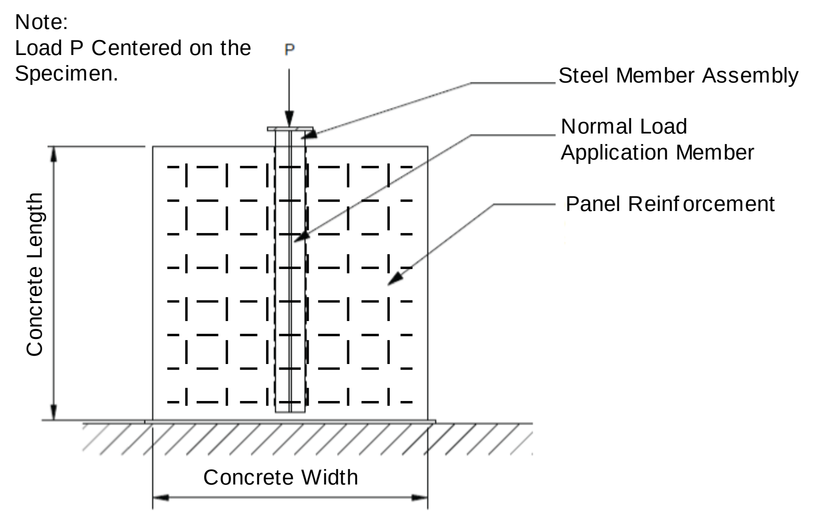

Figure 6.1-1 (d) Specimen Front View

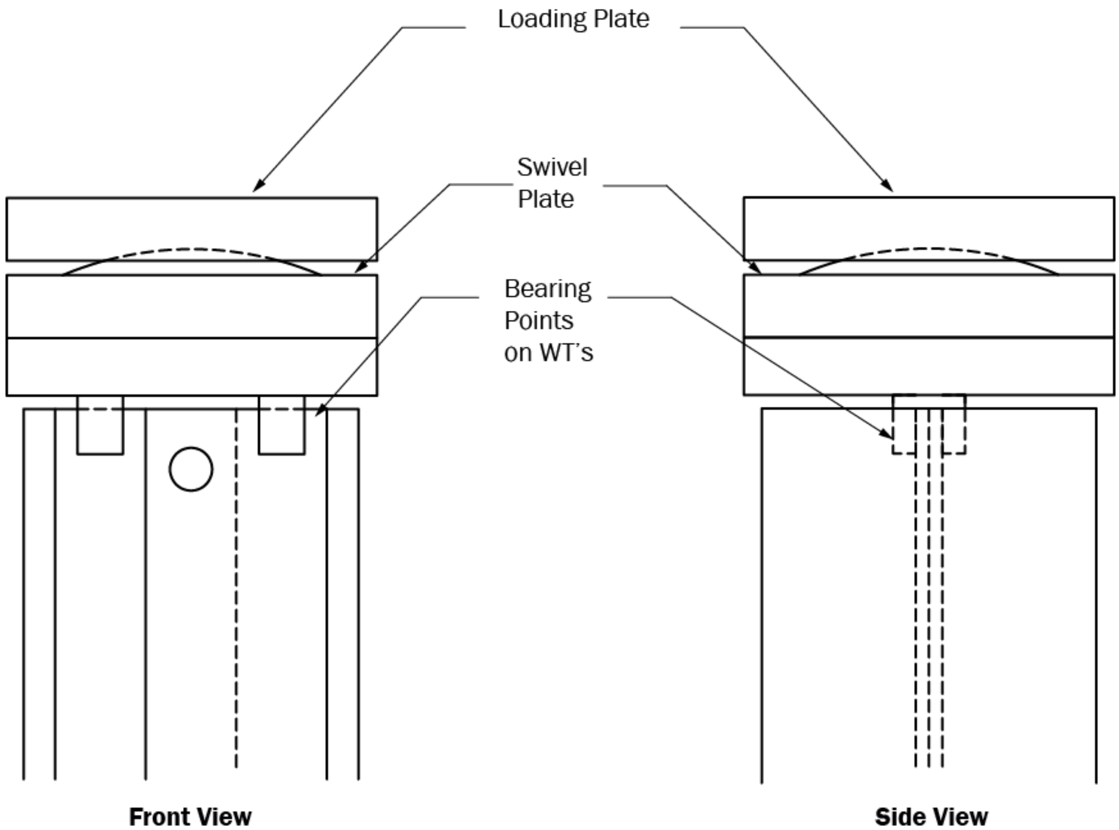

Figure 6.1(e) Loading Plate for Equal Load Sharing

7. Test Specimen

7.1 The number of specimens tested shall comply with the requirements of Section K2 of 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 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 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. The compressive strength tests shall be conducted within 24 hours of the *composite shear connection* load test series. 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.

Commentary:
Standard curing is expected to result in the concrete reaching or exceeding the specified compressive strength. Field curing is expected to result in the concrete compressive strengths closer to that of the test specimens.

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, reinforcement shall be placed outside the anchorage zone, 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 within the anchorage zone.

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, prior to placement of the steel deck or cold-formed steel sheet on the flanges of the steel supporting member, there shall be no additional fastening of the steel deck panel to the steel support 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 steel support 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:
Structural tee (WT) or channel sections are commonly used in tests. The two halves of the test specimen will be stood up and bolted together through the stems of the WT or through the webs of the channels.

8.4 Load Application

8.4.1 Initial Loading. A steel loading plate of adequate size shall be placed over the steel member. A representative loading plate configuration is shown in Figure 6.1(e). 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 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, less than or equal to 10 percent of the concurrent axial load, is permitted to be applied concurrently to the surface of the two concrete elements.

Commentary

The normal load magnitude stipulated in Section 8.4.2 reflects the applications involving flexural strength of steel-concrete composite members in positive bending. As such, the application of the normal load, which results in beneficial friction and local concrete confinement in the zone of anchorage and imposition of consistent curvature between the concrete and the steel component of the composite member, is meant to simulate the commensurate effect of normal load in a full-scale composite member. When this *Standard* is used for other purposes, such as to address the shear connection in diaphragm applications, the magnitude of the normal load should be limited to the magnitude consistent with the application considered with due consideration to applicable loads and load combinations governing the magnitude of the normal load.

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 30 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, in accordance with Figures 6.1(b) and 6.1(c), respectively. For double-stud configurations, the pattern of adjacent connectors shall comply with the manufacturer's instructions (in-line, alternating, etc.).

9. Data Evaluation

9.1 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 AISI S100.

9.2 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, 8 and 9. 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-deformation 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).

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