AISI S913-17

American Iron and Steel Institute

AISI STANDARD

Test Standard for Determining the Strength and Deformation Behavior of Hold-Downs Attached to Cold-Formed Steel Structural Framing

2017 Edition

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2017Edition

Approved by

the AISI Committee on Specifications for the Design of

Cold-Formed Steel Structural Members

The material contained herein has been developed by the American Iron and Steel Institute (AISI) 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 provide methods to determine both the strength and deformation behavior of hold-downs used in cold-formed steel light-frame construction.

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.

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

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AISI S913-17
TEST STANDARD FOR DETERMINING THE STRENGTH AND DEFORMATION BEHAVIOR OF HOLD-DOWNS ATTACHED TO COLD-FORMED STEEL STRUCTURAL FRAMING

1. Scope

1.1 This Standard provides methods to determine both the strength and deformation behavior of *hold-downs* used in cold-formed steel light-frame construction.

User Note:
- This Standard is specifically applicable to *hold-down devices* as employed in lateral load resisting shear walls. If the Standard is used for other applications, the engineer of record or the test agency must define the applicable limits as required in Section 10.1.2 and 10.1.3.
- Illustrated in Figure 1 are some typical *hold-downs*, but there are many other configurations.

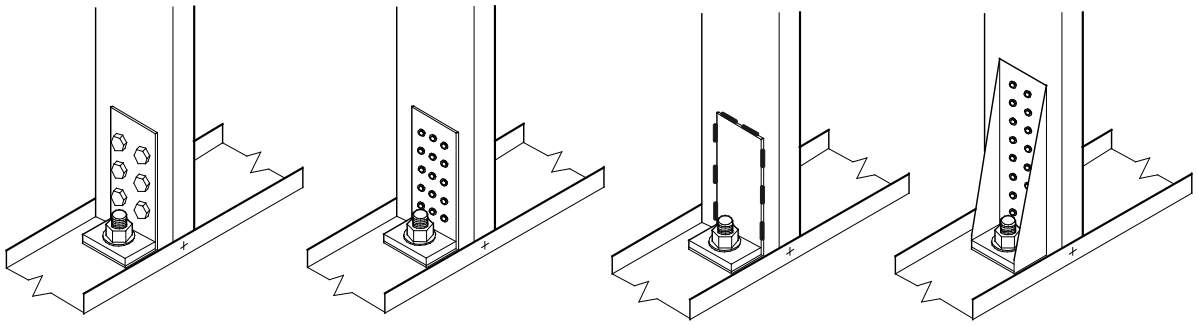

Figure 1 - Typical Hold-Down Assemblies

1.2 The strength of *hold-downs* is determined by testing a *hold-down device* using a steel fixture (Section 8.2) or by testing a *hold-down assembly* in accordance with this Standard.

1.3 The deformation of *hold-downs* is determined by testing a *hold-down assembly* (Section 8.3) in accordance with this Standard.

1.4 This Standard applies to *hold-downs* attached to the cold-formed steel structural framing by use of welds or *fasteners* and to the supporting structure using anchor bolt(s)/rod(s).

1.5 This Standard consists of Sections 1 through 11 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 Iron and Steel Institute (AISI), Washington, DC:

AISI S100-16, *North American Specification for the Design of Cold-Formed Steel Structural Members*

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

A370-16, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

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

IEEE/ASTM SI10-10, *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.

Connection. Combination of structural elements and joints used to transmit forces between two or more members.

Fastener. Bolts, screws, power-driven pins or nails, clinches, or other mechanical *fasteners*.

Hold-Down. Device used to resist uplift of the chords of shear walls, uplift on cold-formed steel members resisting uplift, or lateral loads for wall anchorage.

Hold-Down Device. See *hold-down*.

Hold-Down Assembly. Assembly consisting of the following components: (1) a *hold-down device*, (2) anchor bolt(s)/rod(s) attached to the seat of the device, (3) cold-formed steel member(s) having specified dimensions and properties, (4) *fasteners* or welds used to attach the *hold-down device* to the cold-formed steel member(s), and, if applicable, (5) bearing plates or washers used to enhance the performance of the *hold-down assembly*.

4. Units of Symbols and Terms

Any compatible system of measurement units is 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).

5. Measurement Precision

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

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 E4-16, *Standard Practices for Force Verification of Testing Machines*.

5.2 Deflections shall be recorded to a precision of 0.001 in. (0.025 mm).

6. Test Fixture

The test fixture shall consist of either:

(a) A hydraulic or screw-operated testing machine capable of operating at a constant rate of motion of the movable crosshead or a constant rate of loading, and a calibrated force-measuring device, or

(b) A hydraulic cylinder with a steel fixture, and a calibrated load cell.

7. Test Specimen

7.1 The test specimen shall consist of the tested *hold-down device* and, in the case of the *hold-down assembly* test, the *fasteners* used to connect the *hold-down device* to the cold-formed steel member(s) specified for use with the *hold-down device*.

7.2 The number of specimens tested shall comply with the requirements of Section K2.1 of AISI S100.

7.3 The mechanical properties of the tested *hold-down device*, including yield stress, tensile strength, percent elongation, and uncoated base steel thickness shall be determined. Standard tensile tests of the steel from which the *hold-down device* was produced shall be conducted in accordance with ASTM A370 and Section K2.1.1(d) of AISI S100.

7.4 *Fasteners* used in *hold-down assembly* testing shall be selected from one manufacturer's lot at random and installed in a manner that is representative of field conditions.

7.5 Welding, clinching or other fastening techniques are permitted in a manner that is representative of field conditions.

8. Test Setup

8.1 General

8.1.1 *Hold-down devices* and *assemblies* shall be tested individually in such a manner to simulate the essential function of the *hold-down device* or *assembly*. Test loads shall be applied with reference to the intended end-use application of the *hold-down device* or *assembly*.

8.1.2 The anchor bolt/rod, which is attached to the seat of the *hold-down device*, shall be fastened to the test apparatus in such a manner that the *connection* to the test bed does not affect the test results. Additionally, the anchor bolt/rod shall be installed through the hole in the bearing seat of the *hold-down device* and attached to the device with a nut and washer in accordance with the end-use application as prescribed by the manufacturer's installation instructions.

8.1.3 When testing a bolted *hold-down device* or *assembly*, the nuts used with the bolts to the steel fixture or cold-formed steel member(s) shall only be snug tight, to remove the effects of clamping, unless a torque is specified in the end use.

8.2 Hold-Down Device Test Using a Steel Fixture (Figure 2)

8.2.1 For tension load testing, the anchor bolt/rod shall be long enough to provide a minimum gap of 1.0 in. (25.4 mm), measured from the seat of the *hold-down device* to the test bed (See Figure 2(a)). Alternatively, the *hold-down device* is permitted to be installed directly (e.g., flush) on the test bed if this is consistent with the manufacturer's installation instructions (See Figure 2(b)).

8.2.2 To minimize friction forces between the *hold-down device* and the steel fixture, a low friction material such as Teflon® or polyethylene shall be inserted between the device and steel fixture before load testing.

8.2.3 Bolt(s), used to attach the device to the steel fixture, is permitted to be higher strength than specified for intended use with no load reduction to preclude failure

prior to *hold-down device* failure; however, the dimensions of bolt(s) diameter, nut, and washer, if used, shall be in accordance with the end-use application and the manufacturer's installation instructions.

8.2.4 Anchor bolt(s)/rod(s) is permitted to be higher strength than specified for intended use with no load reduction to preclude failure prior to *hold-down device* failure; however, the anchor bolt(s)/rod(s) diameter and the nut dimensions shall be in accordance with the end-use application and manufacturer's installation instructions. For optional compression testing, the nut and washer dimensions shall be in accordance with the end-use application and the manufacturer's installation instructions.

8.2.5 For optional compression load testing with the *hold-down device* in the raised setting condition (See Figure 2(a)), the maximum unbraced length of the test anchor bolt(s)/rod(s) intended for use with the *hold-down device* shall be as specified by the *hold-down* manufacturer. For the *hold-down device* in the raised setting condition (Figure 3(a)), a minimum of a 1.0 in. (25.4 mm) gap shall be provided between the *hold-down device* and the test bed.

User Note:
The unbraced length of the anchor bolt/rod may be taken as the distance between the nut below the *hold-down* and the nut above the test bed that is installed for the compression test.

8.2.6 When testing a *hold-down device* on a steel fixture, the deflection measurement device shall measure the relative movement between the *hold-down device* and the steel test fixture. Displacement shall be measured between the top of the anchor bolt/rod attached at the seat of the device and a fixed reference point on the steel fixture just above the device (See Figure 2).

8.2.7 An additional force measurement device shall be used to measure the anchor bolt force when the *hold-down device* is installed directly (i.e., flush) on the test bed.

Commentary:
Hold-down devices installed directly (i.e., flush) on a rigid base such as the test bed or a concrete foundation are subject to prying action. Depending on the configuration of the *hold-down*, the anchor bolt force may be indeterminate.

8.2.8 Low friction material is permitted to be placed at the top and bottom of the *hold-down device* or steel fixture to resist horizontal forces that may be a result of eccentricities in the test setup.

8.3 Hold-Down Assembly Test (Figure 3)

8.3.1 The *hold-down assembly* test setup shall consist of the cold-formed steel member(s) specified for use with the *hold-down device*; welds or *fasteners* specified for attaching the device to the cold-formed steel member(s); and, for tension load testing, an anchor bolt/rod long enough to provide a minimum gap of 1.0 inch (25.4 mm), measured from the seat of the *hold-down device* to the test bed (see Figure 3(a)). Alternatively, *the hold-down* is permitted to be installed directly (i.e., flush) on the test bed if this is consistent with manufacturer's installation instructions (see Figure 3(b)).

8.3.2 Installation of the *hold-down device* to the cold-formed steel member(s) shall

maintain *fastener* end and edge distances as expected in field conditions.

8.3.3 Specified bolt strength used in the test shall be in accordance with the end-use application and the manufacturer's installation instructions.

8.3.4 Anchor bolt(s)/rod(s) is permitted to be higher strength than specified for intended use with no load reduction to preclude failure prior to *hold-down device* or cold-formed steel member(s) failure; however, the anchor bolt(s)/rod(s) diameter and the nut dimensions shall be in accordance with the end-use application and the manufacturer's installation instructions.

8.3.5 For optional compression load testing, the maximum unbraced length of the test anchor bolt(s)/rod(s) intended for use with the *hold-down assembly* shall be as specified by the *hold-down* manufacturer. The nut and washer dimensions shall be in accordance with the end-use application and the manufacturer's installation instructions. For the *hold-down assembly* in the raised setting condition (Figure 3(a)), a minimum of a 1.0 in. (25.4 mm) gap shall be provided between the *hold-down device* and the test bed.

User Note:
The unbraced length of the anchor bolt/rod may be taken as the distance between the nut below the *hold-down* and the nut above the test bed that is installed for the compression test.

8.3.6 For optional compression load testing with the *hold-down assembly* in the raised or flush setting conditions (Figures 3(a) and 3(b)), a minimum of a 1.0 in. (25.4 mm) gap shall be provided between the cold-formed steel member(s) and test bed to ensure that the bearing strength of the cold-formed steel member(s) is not included in the available compression strength of the *hold-down*.

8.3.7 When testing a *hold-down assembly* to a cold-formed steel member(s), the deflection measurement device shall measure the relative movement between the cold-formed steel member(s) and the test bed. Displacement shall be measured between the cold-formed steel member(s) and a fixed reference point on the test bed where the anchor bolt/rod is attached. Placement of the deflection measurement device shall ensure accurate measurement of the assembly displacement that includes deformation and rotation of the body of the *hold-down device*, slip between the device and the cold-formed steel member(s), and *fastener* slip (and anchor bolt/rod elongation, when applicable) (See Figure 3).

8.3.8 A force measurement device shall be used to measure the anchor bolt force when the *hold-down device* is installed directly (i.e., flush) on the test bed.

Commentary:
Hold-down devices installed directly on a rigid base, such as the test bed or a concrete foundation, are subject to prying action. Depending on the configuration of the *hold-down*, the anchor bolt force may be indeterminate.

8.3.9 Low friction material is permitted to be placed at the top and bottom of the *hold-down device* or cold-formed steel member(s) to resist horizontal forces that may be a result of eccentricities in the test setup.

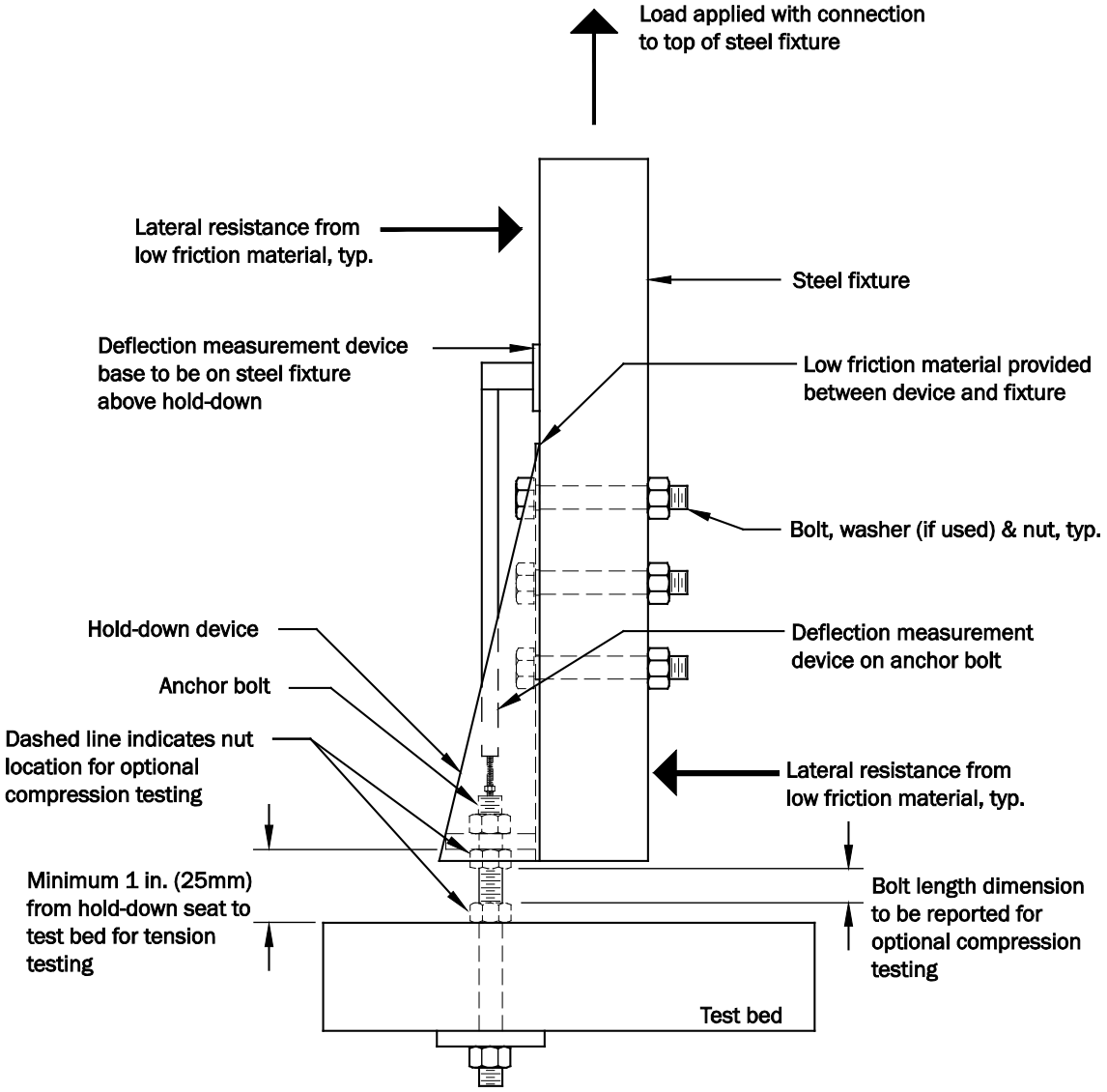

Figure 2(a) - Tension Load Test Setup for a Single Hold-Down Device

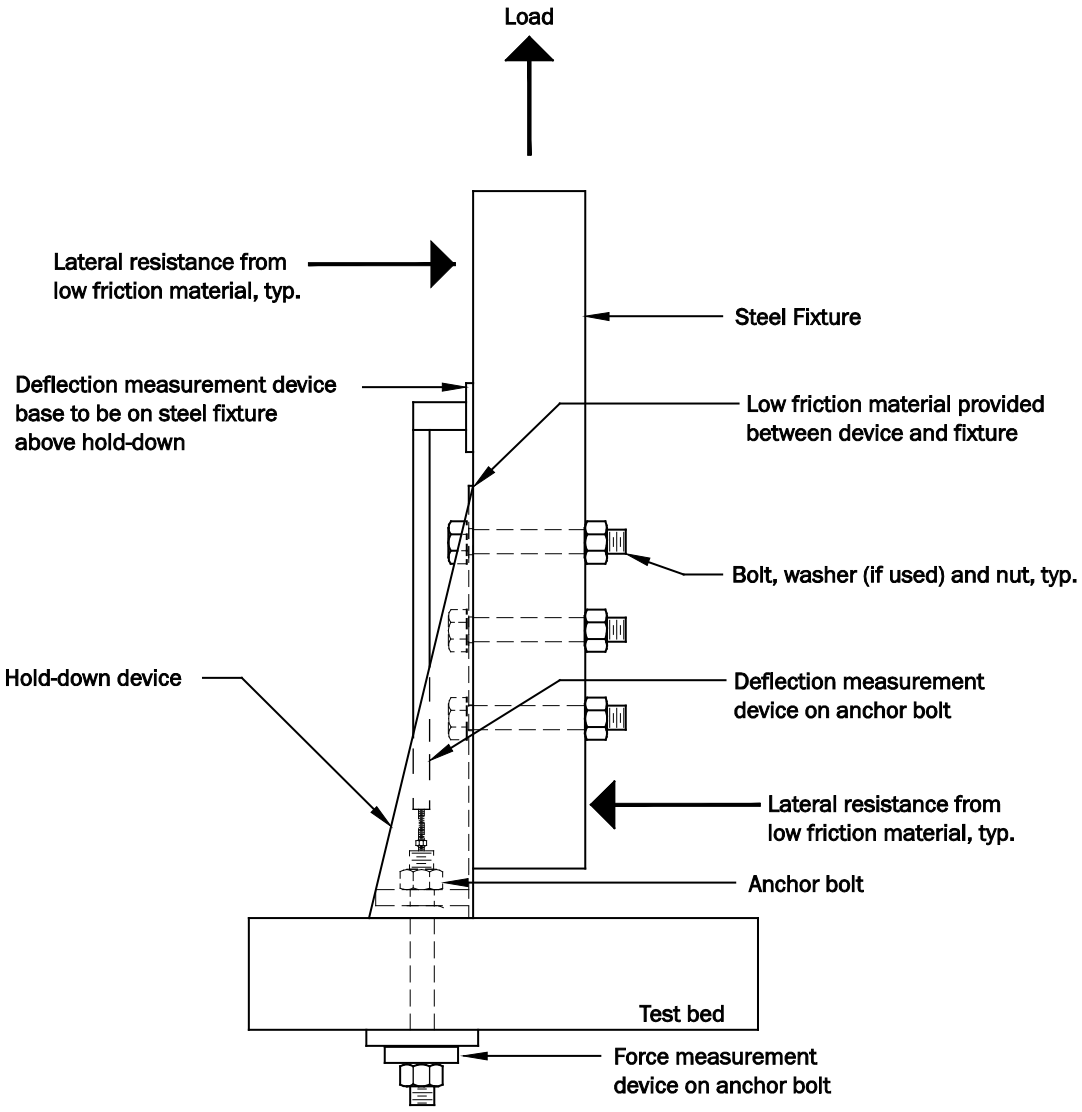

Figure 2(b) - Tension Load Test Setup for a Single Hold-Down Device Flush to Test Bed

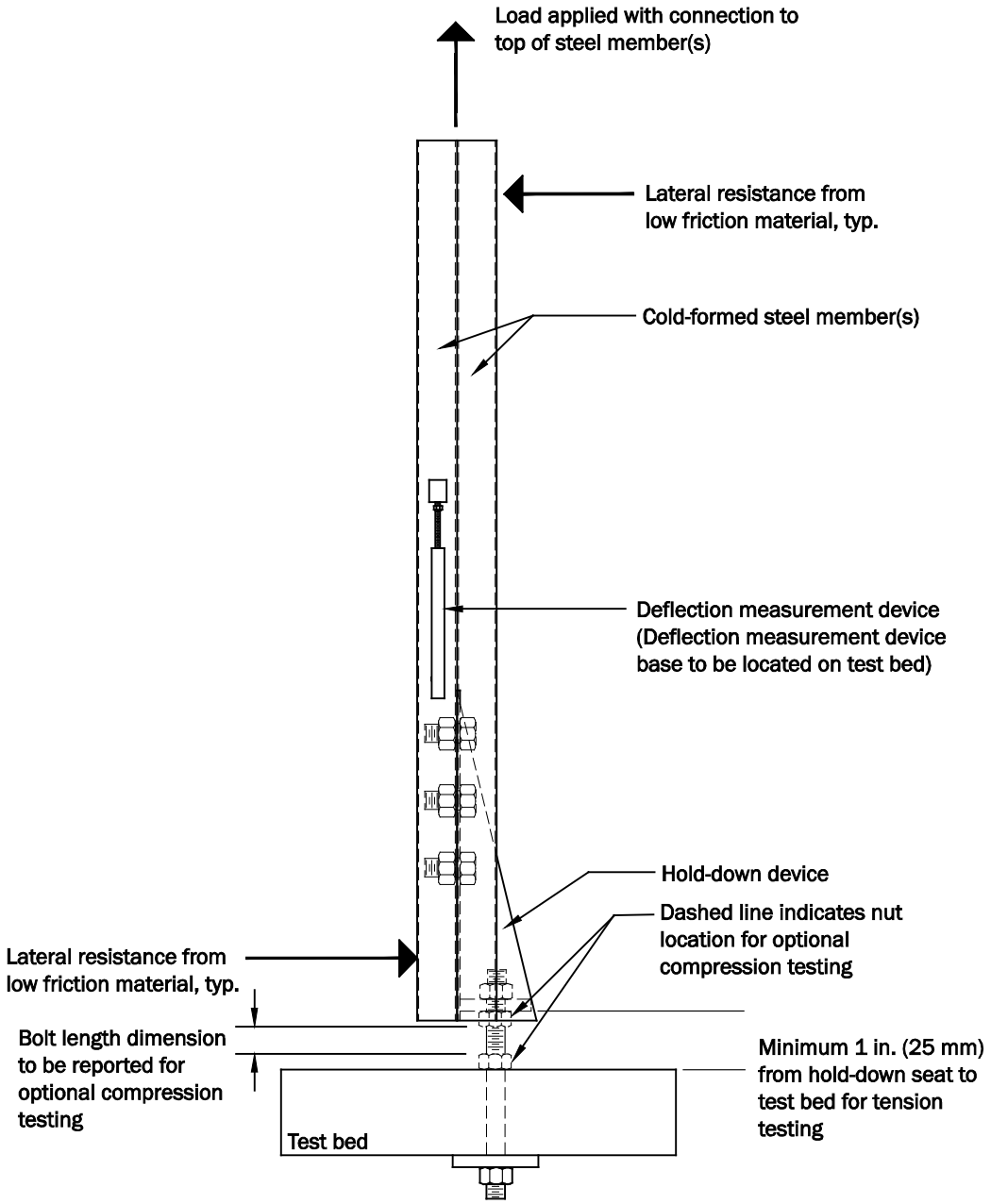

Figure 3(a) - Tension Load Test Setup for a Single Hold-Down Assembly

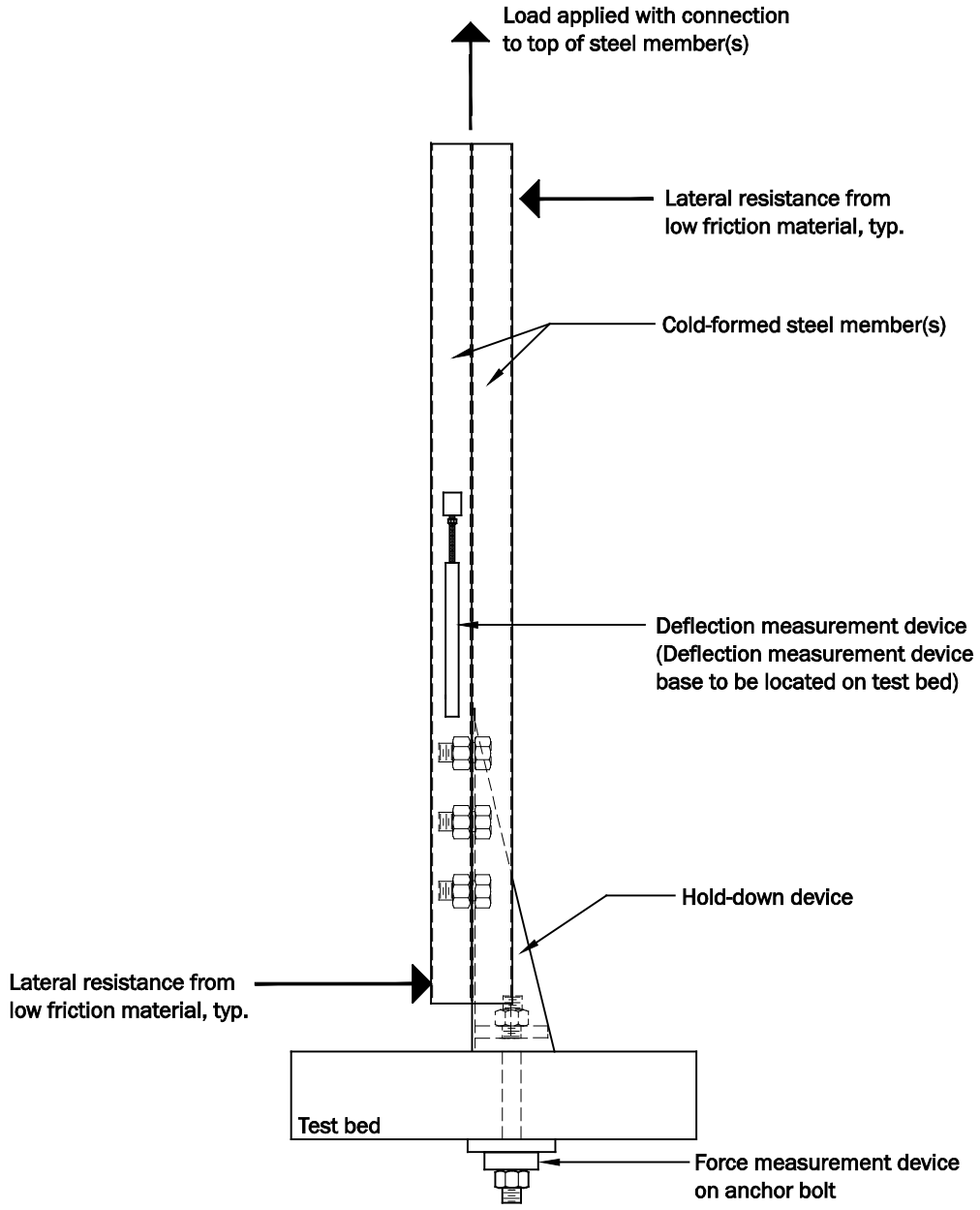

Figure 3(b) - Tension Load Test Setup for a Single Hold-Down Assembly Flush to Test Bed

9. Test Procedure

9.1 An initial load, or preload, shall not be applied for tension (uplift) load or compression load (optional) testing of *hold-down devices* or *hold-down assemblies*.

Commentary:
An initial load or preload is not representative of field conditions.

9.2 The test load shall be applied at a uniform rate between 0.03 in. and 0.20 in. (0.8 mm and 5.1 mm) per minute until failure or maximum load.

9.3 Deflections shall be recorded at a sufficient number of load levels to permit the establishment of a load-deflection curve. At least eight readings shall be taken prior to reaching the deflection limit state and the tested deflection limit shall be recorded. Readings shall be taken throughout the test and not be grouped such as at the beginning, middle or end of the test.

9.4 Tension Load Test

9.4.1 *Hold-down devices* shall be tested such that a tension load is applied in reference to the intended application of the device where attached to a steel fixture as described in Section 8.2.

9.4.2 *Hold-down assemblies* shall be tested such that a tension load is applied in reference to the intended application of the assembly where attached to a cold-formed steel member(s) as described in Section 8.3.

9.5 Compression Load Test

9.5.1 Compression load testing shall be conducted where the intended use of the *hold-down device* will include resistance to compression.

9.5.2 *Hold-down devices* shall be tested such that a compression load is applied in reference to the intended application of the device where attached to a steel fixture as described in Section 8.2.

9.5.3 *Hold-down assemblies* shall be tested such that a compression load is applied in reference to the intended application of the assembly where attached to a cold-formed steel member(s) as described in Section 8.3.

10. Data Evaluation

10.1 The available strength (i.e., allowable strength and/or design strength [factored resistance]) based on tests shall be the least value determined in accordance with Sections 10.1.1, 10.1.2 and 10.1.3, as applicable.

10.1.1 The available strength [factored resistance] shall be determined in accordance with the procedures described in Section K2.1 of AISI S100.

User Note:
Table K2 of Section K2 of AISI S100 provides statistical data. When the device itself fails, then the statistical values for "Other Member Limit States" must be used to evaluate the allowable strength and/or design strength [factored resistance].

10.1.2 For *hold-downs* used in shear walls or those that otherwise contribute to the story drift, allowable strength shall be determined by averaging the test load at the applicable deflection limit prescribed in Section 10.5 and multiplying by 0.7.

Commentary:
Hold-down devices are load rated based on the lesser of a strength limit state and a deflection limit state. The allowable strength adjustment factor of 0.7 is taken from the load combinations of ASCE 7-10, *Minimum Loads for Buildings and Other Structures*, to adjust the deflection limit state value for Allowable Strength Design (ASD). Another reduction factor may be more appropriate in other building code jurisdictions.

10.1.3 For *hold-downs* used in shear walls or those that otherwise contribute to the story drift, design strength [factored resistance] shall be determined by averaging the test load at the applicable deflection limit prescribed in Section 10.5.

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

10.3 The *hold-down device* test using a steel fixture or the *hold-down assembly* test shall be used to determine the tested strength of the *hold-down*. The strength of the *hold-down connection* shall be the lowest of the tested strength, the strength of the cold-formed steel member to which the *hold-down* is to be attached, or the strength of the screw, bolt, and/or welded *connections* as determined from the applicable section of AISI S100. The *hold-down assembly* test shall be required to determine the strength of the *hold-down connection* where the *hold-down connection* to the cold-formed steel members is with *fasteners* other than what is recognized in AISI S100. The *hold-down assembly* test is permitted to be used to determine the tested strength of the *hold-down* in lieu of the *hold-down device* test.

10.4 The *hold-down assembly* test, in which the *hold-down* is attached to cold-formed steel members, shall be used to obtain the displacement of the *hold-down connection* inclusive of the *hold-down* displacement.

10.5 The deflection limit for *hold-downs* used in shear walls or those that otherwise contribute to story drift shall be 0.185 in. (4.7 mm) for the *hold-down device* test and 0.25 in. (6.4 mm) for the *hold-down assembly* test, unless otherwise defined by the applicable building code or a design standard approved by the authority having jurisdiction.

Commentary:
These deflection limits are based on traditionally accepted values for the seismic design of shear walls, noting that the seismic story drift is to be checked at the strength level in accordance with ASCE 7. A 1/8-in. (3.18-mm) deflection limit for ASD was generally used for *hold-downs* attached to a steel test apparatus and this was increased to 3/16 in. (4.76 mm) to account for *fastener* slip when the *hold-down* was tested to actual studs. As it is desired to have an LRFD as well as an ASD load rating, the 1/8-in. (3.18 mm) and 3/16-in. (4.76 mm) deflection limits were increased to 0.185 in. (4.70 mm) and 0.25 in. (6.35 mm). The load at these higher deflection limits is the LRFD deflection load limit and the designer multiplies the load at these deflection values by 0.7 to determine the ASD deflection load limit (See Section 10.1.2). This test standard conservatively applies these limits to all load applications in order to avoid multiple load ratings for the same *hold-down*.

11. Test Report

11.1 The test report shall include a description of the tested *hold-down device* and/or *assembly* and device, including a drawing that details all pertinent dimensions of the assembly and device. The description shall also include information concerning each component of the tested *hold-down assembly*.

11.2 The test report shall include the measured steel mechanical properties of the *hold-down device*, and cold-formed steel member(s).

11.3 The test report shall include a description of any modifications made to the cold-formed steel member(s) used in *hold-down assembly* testing.

11.4 The test report shall include a description of the bolts, screws, welds or other *fasteners*, and the anchor bolt/rod length dimension as shown in Figures 2(a), 2(b), 3(a), and 3(b).

11.5 When testing a bolted *hold-down device*, it shall be reported if the bolt threads are excluded or included in the shear plane between the device and the steel fixture.

11.6 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 as stipulated in Sections 6, 8, and 9. Additionally, photographs shall supplement the detailed drawings of the test setup.

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

11.8 The test report shall include individual load values observed description of the nature, type and location of failure exhibited by each *hold-down assembly* or device tested; and a description of the general behavior of the test assembly or device during load application. Additionally, photographs shall supplement the description of the failure mode(s).

11.9 The test report shall include a description of the test method and loading procedure used, as well as the rate of loading or rate of motion of the crosshead movement.

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