



Designation: D7147 – 21

Standard Specification for Testing and Establishing Allowable Loads of Joist Hangers¹

This standard is issued under the fixed designation D7147; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope

1.1 This specification covers a procedure for evaluating metal devices used for wood-to-wood, wood-to-concrete, wood-to-concrete masonry, and wood-to-steel connections. This method is intended for use with devices used to connect joists, beams, and girders together. These devices are commonly described as joist hangers.

1.2 This specification describes test methods for evaluating the capacities of joist hangers subject to vertical and torsional loading.

1.3 This specification provides a method of assigning allowable loads to joist hangers based on measured strength and deformation characteristics. Information obtained by the provisions of this specification is applicable to design when using the Allowable Stress Design method.

1.4 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:²

¹ This specification is under the jurisdiction of ASTM Committee D07 on Wood and is the direct responsibility of Subcommittee D07.05 on Wood Assemblies.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

- C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
- C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
- C90 Specification for Loadbearing Concrete Masonry Units
- C270 Specification for Mortar for Unit Masonry
- C1314 Test Method for Compressive Strength of Masonry Prisms
- D245 Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber
- D9 Terminology Relating to Wood and Wood-Based Products
- D1038 Terminology Relating to Veneer, Plywood, and Wood Structural Panels
- D1761 Test Methods for Mechanical Fasteners in Wood and Wood-Based Materials
- D2395 Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials
- D3737 Practice for Establishing Allowable Properties for Structural Glued Laminated Timber (Glulam)
- D4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials
- D5055 Specification for Establishing and Monitoring Structural Capacities of Prefabricated Wood I-Joists
- D5456 Specification for Evaluation of Structural Composite Lumber Products
- D7438 Practice for Field Calibration and Application of Hand-Held Moisture Meters
- E4 Practices for Force Verification of Testing Machines
- E8/E8M Test Methods for Tension Testing of Metallic Materials
- E575 Practice for Reporting Data from Structural Tests of Building Constructions, Elements, Connections, and Assemblies
- F606/F606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
- F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
- F1575 Test Method for Determining Bending Yield Moment of Nails

2.2 Other Standards:

- AWC NDS National Design Specification for Wood Construction³
- AISI S100 North American Specification for the Design of Cold-Formed Steel Structural Members⁴
- ANSI/AISC 360 Specification for Structural Steel Buildings⁵
- ANSI/ASME B18.2.1 Square, Hex, Heavy Hex, and Askew Head Bolts and Hex, Heavy Hex, Hex Flange, Lobed Head, and Lag Screws (Inch Series)⁶
- ACI 318/318R Building Code Requirements for Structural Concrete and Commentary⁷

3. Terminology

3.1 The following section defines terms used in this specification. See Terminology D9 and D1038 for other terminology.

3.2 Definitions:

3.2.1 header—a member supporting a joist hanger. A header may also be referred to as a “supporting” member.

3.2.2 joist—a bending member supported by a joist hanger. A joist may also be referred to as a “supported” member.

3.2.3 joist hanger—a metal device, usually cold-formed from light-gage steel sheet or welded from steel plate, used to transfer loads from a joist to a header member or wall in building construction. Face-mount joist hangers contact the side surface of the header and do not contact the top of the header. Top-mount hangers are joist hangers that contact the side and top surface of the header.

3.2.4 sawn lumber—see definition for lumber in Terminology D9.

3.2.5 structural composite lumber (SCL)—see Specification D5456.

3.2.6 structural glued laminated timber (glulam)—see Practice D3737.

3.2.7 wood I-joists—see Specification D5055.

4. Significance and Use

4.1 Joist hangers are used to transfer vertical loads from a joist to a header in building construction. In addition to vertical load transfer, joist hangers may provide torsional resistance for the ends of a joist. The performance of this connection is influenced by a number of variables, such as the properties of the hanger, the joist material, the header material, and the fasteners. The test described in this specification provide for consistency in evaluating the performance of such assembled units.

³ Available from American Wood Council (AWC), 222 Catoctin Circle SE, Suite 201, Leesburg, VA 20175.

⁴ Available from American Iron and Steel Institute (AISI), 1101 17th St., NW, Suite 1300, Washington, DC 20036.

⁵ Available from American Institute of Steel Construction (AISC), One E. Wacker Dr., Suite 3100, Chicago, IL 60601-2001.

⁶ Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5900, http://www.asme.org.

⁷ Available from American Concrete Institute (ACI), 38800 Country Club Dr., Farmington Hills, MI 48331-3439, http://www.concrete.org.

5. Summary of Test Method

5.1 Vertical Load Test—Test specimens consisting of a length of joist supported by joist hangers attached to two headers are subjected to a vertical load by a suitable testing machine (see Figs. 1-3), while the vertical load and corresponding deflection of the joist are measured and recorded to provide load-slip data.

5.1.1 Loads applied vertically downward with reference to the intended application of the joist hanger, shall be classified as downward (see Fig. 1).

5.1.2 Loads applied vertically upward with reference to the intended application of the joist hanger, shall be classified as uplift (see Fig. 2).

5.2 Torsional Moment Test (optional)—A test method is provided in Appendix X1 for torsional moment capacity evaluation of hangers. This test consists of a joist supported by two joist hangers attached to headers (see Figs. X1.1 and X1.2). The movement of the joist with respect to the headers is measured and recorded to provide data for calculating angular rotation and load-deflection relationships.

6. Apparatus

6.1 Testing Machine—A testing machine that is capable of operation at a constant rate of motion of the movable crosshead or a constant rate of loading and a force-measuring device that is calibrated in accordance with Practices E4.

6.2 Displacement Gage—All tests shall use a dial gage(s), or equivalent, to measure the relative movement between the joist and header. Devices used for this purpose shall have a least reading of 0.001 in. (0.02 mm).

7. Test Materials

7.1 Wood—All wood materials shall be of structural quality with allowable values substantiated by accepted procedures, such as those found in Section 2. The specific gravity of the joists and headers shall be determined in accordance with Test Methods D2395, and moisture content of the joists and headers shall be determined in accordance with Test Methods D4442 or Practice D7438. All specific gravities shall be reported on an

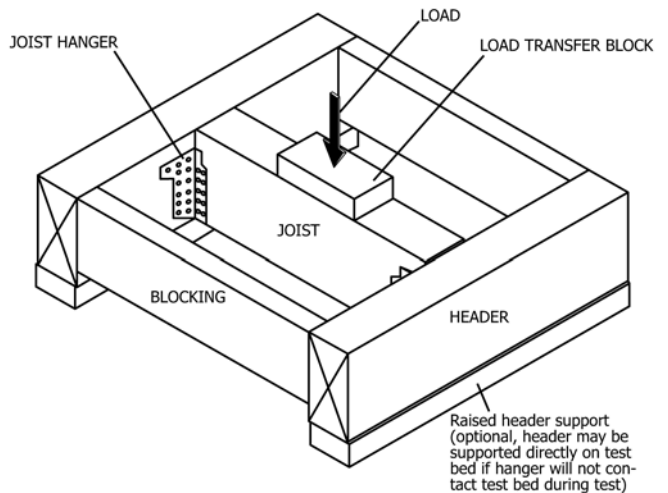


FIG. 1 Typical Vertical Downward Test Setup

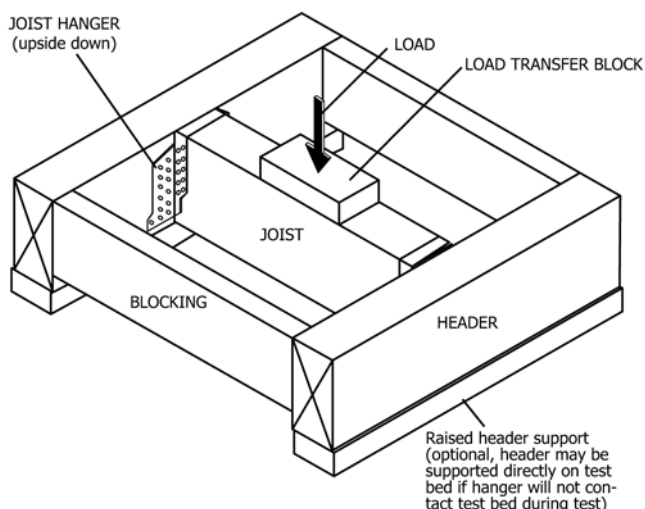


FIG. 2 Typical Uplift Test Setup

oven-dry basis in accordance with Test Methods [D2395](#). Specific gravity measurements taken at moisture contents other than oven-dry shall be adjusted to the oven-dry moisture content in accordance with Appendix X1 of Test Methods [D2395](#).

7.2 Concrete or Masonry:

7.2.1 If concrete is used, a minimum of two concrete test cylinders shall be prepared, stored, and cured in accordance with Practice [C31/C31M](#) from the same batch of concrete used in the joist hanger test specimen. Cylinders shall be tested in accordance with Test Method [C39/C39M](#) within 24 h of the test of the joist hanger.

7.2.2 If masonry is used, the compressive strength of the masonry shall be determined by the prism test method in accordance with Test Method [C1314](#).

7.3 *Steel*—Standard tensile tests of the steel from which the joist hanger was produced shall be conducted in accordance with Test Methods [E8/E8M](#).

7.4 *Fasteners*—Fasteners from the same manufacturer’s lot as were used in the joist hanger test specimen shall be sampled in accordance with Practice [F1470](#) to determine the fastener bending yield strength. Nails and wood screws shall be tested for bending yield strength in accordance with Test Method [F1575](#). Bolts shall be tested in accordance with Test Methods [F606/F606M](#) for the properties relevant to the application.

8. Sampling

8.1 Sampling shall provide for selection of representative test materials except where the tests are designed to specifically address use with particular grades, dimensions, wood species, or other condition. Properties of tested materials shall be permitted to exceed the minimum or nominal values of those properties reported in relevant specifications for that material provided the adjustments to tested results that are addressed in Section [13](#) are made. Structural composite lumber and I-joist materials shall be chosen to represent the grade and species of each product type that conservatively represent the range of similar products to be addressed by each test set.

NOTE 1—It is not uncommon for SCL manufacturers to conservatively assign a design value for fastener performance for a product type (that is, parallel strand lumber, laminated veneer lumber, laminated strand lumber, etc.) that covers multiple species, process variables, and grades. Sampling SCL materials and components made thereof (that is, I-joist flange materials) from the species and grade mix that conservatively addresses the range for a given product type is one way to satisfy this requirement.

8.2 A minimum of three identical tests shall be performed for each selected hanger condition.

9. Test Setup

9.1 A joist hanger test setup shall consist of a joist supported between two headers by the hanger devices to be evaluated.

9.2 Headers shall have a length sufficient to provide the intended hanger-to-header contact for the hanger, for example, space for nailing and bearing as applicable. The minimum header length shall be 18 in. (457 mm). See [Fig. 3](#).

9.3 Joist length shall be in accordance with [Fig. 3](#).

9.3.1 Joist lengths shall be sufficient to prevent contact between joist hangers and any material other than the attached headers and joist. A minimum horizontal clear distance of 3 in. (76 mm) or $\frac{1}{3}$ the joist depth, whichever is smaller, shall be provided between the load transfer block and the hanger seat. A minimum clearance of 0.125 in. (3.18 mm) shall be provided between each end of the joist and abutting material, such as the adjacent header or any hanger section between the header and the joist (see [Fig. 4](#)). Prior to loading, the 0.125 in. (3.18 mm) gap shall be maintained between joist and header by providing blocking, or equivalent, between the ends of the headers.

9.3.2 To minimize header-joist load transfer due to friction, a low friction material with a thickness no greater than 0.063 in. (1.6 mm) shall be inserted into the 0.125 in. (3.18 mm) gap prior to loading.

9.3.3 The seat of the hanger shall be prevented from direct contact with the header during the test unless provisions are made to prevent the hanger seat from gouging into the header or the hanger seat shall be at or below the bottom of the header.

9.4 Header Supports:

9.4.1 Header supports shall provide sufficient bearing to prevent excessive crushing.

9.4.2 No portion of the joist hanger shall bear on any support other than the header during the test. This shall be accomplished by:

9.4.2.1 Using raised supports with a minimum header overhang of $\frac{1}{8}$ in. (3.18 mm) at the inside edges (see [Figs. 1-3](#)), or

9.4.2.2 Using headers that are deeper than the joist by an amount sufficient to ensure that neither the joist nor the hanger contact the test bed.

9.4.3 The test bed or any header supports shall not contact the joist or joist hanger at any time during the test.

NOTE 2—A $\frac{1}{8}$ -in. (3.18 mm) overhang of the header beyond the inside edge of the support has historically been provided to ensure contact does not occur between the joist hanger and the header support.

9.5 Reinforcement of joist members at the area of load application shall be permitted to prevent member failure in bending, shear, or compression perpendicular-to-grain at the applied load, so as to produce: (1) a failure in the joist hanger, (2) a failure of the fasteners between the joist hanger and the

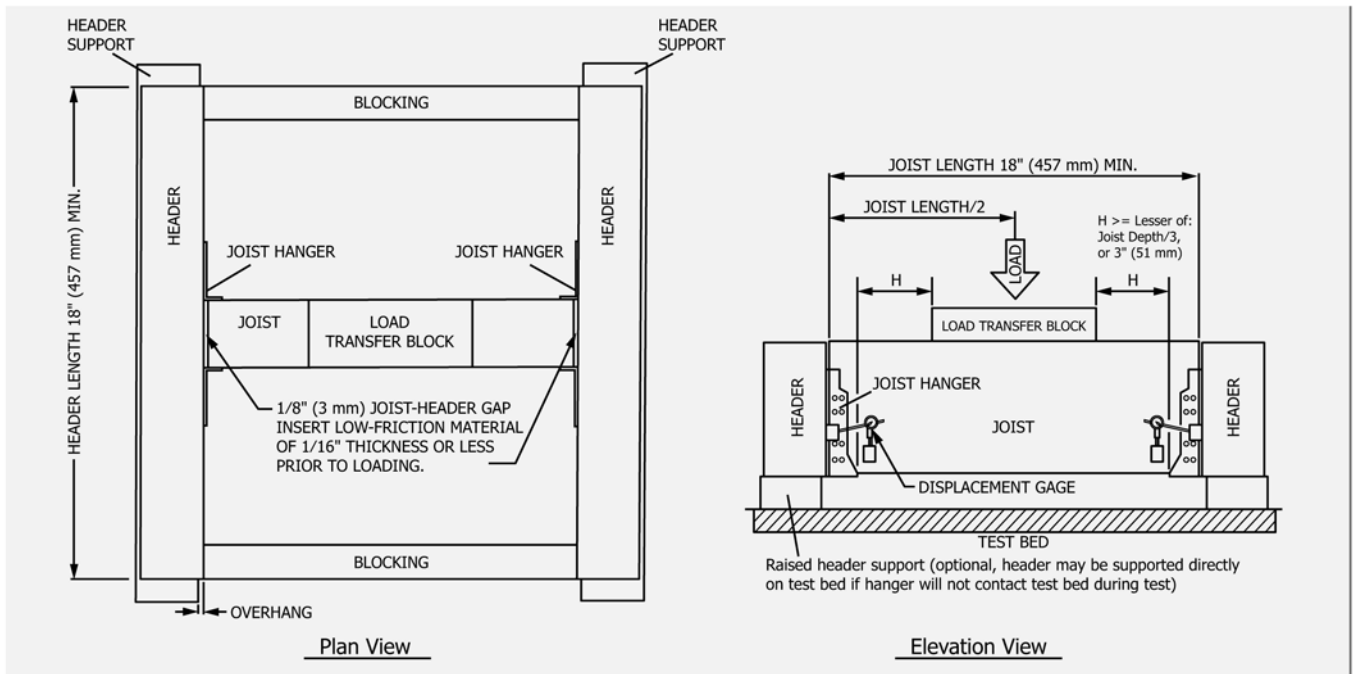


FIG. 3 Vertical Downward Test Setup

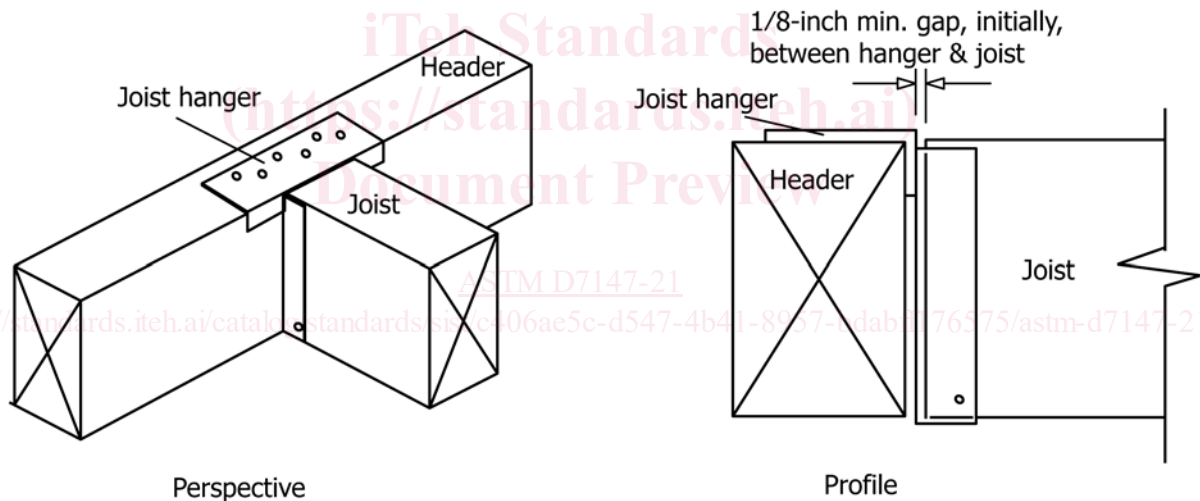


FIG. 4 Required Gap When Portion of Joist Hanger Exists Between Header and Joist

joist, (3) a failure of the fasteners between the joist hanger and the header member(s), or (4) a joist bearing failure at the hanger. The length of joist reinforcement shall be no closer than 2 in. (51 mm) from the end of each hanger.

9.6 Blocking between the headers or alternate methods shall be provided to prevent rotation of the headers inward towards the joist. Tensile reinforcement between the headers shall be permitted to prevent rotation of the headers outward away from the joist. Such reinforcement shall not contact the joist hangers or otherwise interfere with their performance.

9.7 Where a hanger device is of a design that is not adaptable to the test setup described above, necessary departures shall be permitted, provided the altered setup will

perform the essential function of testing the joist hanger device, and provided that such departures are reported in the test report in detail.

10. Conditioning

10.1 Test specimens fabricated and tested with dimension lumber shall have a moisture content of not less than 11 % unless adjustments are made to test results in accordance with 13.2.

10.2 For structural composite lumber, structural glued-laminated wood and wood I-joist products, tests shall be made at a moisture content of no less than 7 %. When the member consists of different elements, such as an I-joist flange, a web,

or other wood elements, or a combination thereof, moisture content shall be measured of all parts in contact with the joist hanger or its fasteners.

10.2.1 *Exception*—The moisture content of plywood and oriented strand board elements need not be measured.

11. Procedure

11.1 The following properties must be determined for materials used in the test:

- (1) tensile strength of hanger steel,
- (2) specific gravity of wood materials as outlined in 13.5.2 – 13.5.4, and
- (3) bending yield strength of the fasteners.

11.2 Vertical movement of the joist with respect to each header shall be measured with a minimum of two dial gages or other suitable device as depicted in Fig. 3. The dial gage shall measure movement of any point along the depth of the joist (top, bottom, or side) located within 1.5 in. (38 mm) from the end of the joist. Dial gage bases shall be attached to the bottom half of the header to the center of the gage base or attached to the test machine bed.

11.2.1 *Exception*—When the joist setup is inverted for uplift testing, the dial gage or other suitable device shall be located on the joist within 1 in. (25 mm) from the end of the hanger seat.

11.3 The load shall be centered over the joist and be transferred from the crosshead to the test specimen in a manner that will assure equal distribution of the load to both ends of the joist. The load shall be applied over a sufficient joist length to prevent excessive crushing under the loading head and shall conform to the requirements of Section 9.

11.4 For downward load capacity tests, an initial load, or preload, shall be applied to the joist to seat the test assembly. This preload shall not exceed 20 % of the ultimate load. This load shall then be removed and the dial gages shall be set to zero. The preload shall be recorded and reported for each test specimen.

11.5 An initial load, or preload, shall not be applied for uplift load capacity tests.

11.6 The load shall be applied at a uniform crosshead rate between 0.03 and 0.20 in. (0.8 to 5.1 mm) per minute. For all tests, the ultimate load shall not be reached in less than 5 min.

11.6.1 The loads shall be recorded to a precision of 1 % for loads exceeding 1000 lb (4450 N) and 10 lb (44.5 N) for loads not exceeding 1000 lb (4450 N). The deflections shall be recorded to the nearest 0.001 in. (0.02 mm). A sufficient number of readings shall be taken to permit determining the load at a deflection of 0.125 in. (3.18 mm).

11.7 Wood failure modes, such as joist bending failure and joist top surface crushing at the load transfer block, are unrelated to the performance of the joist hanger. When such failure modes occur, it shall be permitted to replace the tests that resulted in these failure modes with additional tests with appropriate reinforcement to prevent the reoccurrence of these failure modes.

12. Report

12.1 The test report shall follow the format of Practice E575, shall include a detailed drawing of the test setup, and shall include the following:

12.1.1 A description of the joist hangers tested including a drawing of the joist hangers showing all pertinent dimensions and material specifications, and a description of the required fasteners,

12.1.2 A description of the joist, headers, and any backer or filler blocking or stiffeners,

12.1.2.1 Actual dimensions, species, grades, specific gravities, moisture contents for each header, and joist of each assembly, including name of the manufacturer for proprietary products,

12.1.2.2 A description of any modifications made to the joist or headers used in the test assembly,

12.1.3 The measured hanger steel properties including yield strength, ultimate strength, and base metal thickness. The base metal thickness shall be permitted to be determined by subtracting the average measured coating thickness from the average measured overall thickness,

12.1.4 A description of the fasteners including the finish, head configuration, head diameter, and markings; the measured length, diameter; and strength properties required in 7.4,

12.1.5 A description of the concrete or masonry properties, including measured properties as required in 7.2, if concrete or masonry was used,

12.1.6 A description of the load transfer block, other blocking, low-friction materials, reinforcement, and any deviations from the standard test setup shown in Figs. 3 and 4,

12.1.7 Data on load-deflection, including the load at the 0.125 in. (3.18 mm) deflection limit, and the maximum test load observed,

12.1.8 Type and location of failure of the specimen,

12.1.9 Number of replications including a description of replications not used as allowed in 11.7,

12.1.10 Loading procedure details, including preload, load rate, and time to maximum load, and

12.1.11 Details of any deviations from the prescribed test setup and test procedures as outlined in this specification.

13. Allowable Joist Hanger Loads Limited by Test

13.1 Joist hanger design values limited by test shall be limited to the materials tested, except as otherwise provided in Section 13. For application to materials used in construction, the construction materials shall satisfy 13.1.1 – 13.1.4.

13.1.1 *Wood*—All wood materials shall be of structural quality with allowable values substantiated by accepted procedures, such as those found in Section 2.

13.1.2 *Steel*—All production steel material shall meet or exceed a specified minimum yield strength, a specified minimum ultimate strength, and a specified minimum thickness.

13.1.3 *Fasteners*—Fasteners used for field installation shall meet or exceed minimum specified cross-sectional dimensions (for example, diameter or width and thickness), length, other relevant dimensions, and relevant material properties.

13.1.4 *Concrete and Masonry*—All concrete and masonry materials shall have structural properties that meet or exceed a minimum specified compression strength.

13.2 Allowable loads for joist hangers based upon test shall be the lesser of the values determined in 13.3 and 13.4. Adjustments to test results shall be made in accordance with 13.5.

13.2.1 The results of all load tests except those tests excluded per 11.7 shall be used to determine the allowable load capacity of the joist hanger.

13.3 Test Strength Limit:

13.3.1 The ultimate load rating shall be the lowest ultimate load per joist hanger divided by 3.0 if less than six replicates are tested. The ultimate load rating shall be the average ultimate load per joist hanger divided by 3.0 when six or more replicates are tested. See 13.5 for adjustments to test results.

13.4 Test Deflection Limit:

13.4.1 For all vertical load tests, the load at 0.125-in. (3.18 mm) deflection shall be recorded for each hanger. The test deflection limit load shall be the average of all of these loads. The load at the specified deflection limit shall be permitted to be interpolated from the test data.

13.5 Adjustments to Test Strength Limit:

13.5.1 The resulting test values shall be multiplied by the lowest of the adjustment factors determined in 13.5.2 – 13.5.4.

NOTE 3—The adjustments outlined in 13.5 are based upon sawn lumber performance and are not applicable to SCL. As outlined in 8.1, SCL members selected for testing should conservatively represent the performance level used to establish its related fastener design properties. No further adjustment of the test data should be undertaken.

13.5.1.1 The following definitions apply to adjustment factors in 13.5.2 – 13.5.4.

NOTE 4—For conversion to SI units: 1 m² = 1550 in.²; 1 MPa = 145 psi.

- A_{joist} = bearing area between the joist and the joist hanger, in.²
- A_{header} = the area on the header subject to compression perpendicular-to-grain from the hanger, in.².
- $F_{c\perp, nominal}$ = 2250 x $G_{nominal}$ – 480, psi.
- $F_{c\perp, tested}$ = 2250 x G_{tested} – 480, psi.
- $F_{u, spec}$ = ultimate strength of the connector steel from the manufacturer's specifications, psi ($\leq F_{u, tested}$).
- $F_{u, tested}$ = measured ultimate strength of the connector steel used in the test specimens, psi.
- $F_{yb, nominal}$ = bending yield strength of the connector fasteners published in the AWC NDS or other approved document, psi ($\leq F_{yb, tested}$).
- $F_{yb, tested}$ = measured bending yield strength of the connector fasteners used in the test specimens, psi.
- $G_{nominal}$ = published specific gravity of the test specimen header material.
- G_{tested} = actual specific gravity of the test specimen header material as determined by 7.1.
- MC_{limit} = moisture content (%) lower limit for wood type as shown in Section 10.

- MC_{test} = moisture content (%) in test samples.
- R_J = adjustment factor (≤ 1.0) applied to test results when joist test materials are stronger than materials used in field applications.
- R_{HF} = adjustment factor (≤ 1.0) applied to test results of face mount hangers when header test materials are stronger than materials used in field applications.
- R_{HT} = adjustment factor (≤ 1.0) applied to test results of top flange hangers when header test materials are stronger than materials used in field applications.
- R_{MC} = adjustment factor (≤ 1.0) applied to test results when the tested moisture content (MC) is less than the lowest allowed moisture content listed in this specification in Section 10.
- R_S = adjustment factor (≤ 1.0) applied to test results when the tested hanger steel is stronger than specified steel for hanger.
- t_{spec} = specified minimum steel thickness joist hanger.
- t_{tested} = measured steel thickness of tested joist hangers.
- $Z_{nominal}$ = sum of all the lateral fastener resistance values according to the AWC NDS or other approved document and based on the following: (1) header material specified for the installation, (2) fastener quantity, type, and size specified for the installation of the hanger to the header and published F_{yb} values, and (3) hanger steel specified for production.
- Z_{tested} = sum of all the lateral fastener resistance values calculated according to the AWC NDS or other approved documents and based on the following: (1) header material tested, (2) fastener quantity, type, and measured size for installation of the hanger to the header and tested F_{yb} values, and (3) hanger steel tested. Also see 13.6.

13.5.2 *Joist Adjustments*—Test values shall be multiplied by the factor R_J to account for joist fastener and compression perpendicular-to-grain strength increases. When the joist consists of multiple components, such as an I-joist with flanges, a web, and blocking at the hanger, R_J shall be calculated for the joist setup. The adjustment factor shall be determined and applied for each joist hanger connection separately using the material properties specific to that connection.

$$R_J = (F_{c\perp, nominal} A_{joist} + Z_{nominal}) / (F_{c\perp, tested} A_{joist} + Z_{tested}) \leq 1.0 \quad (1)$$

13.5.3 *Header Adjustment-Face Mount Hangers*—Test values shall be multiplied by the factor R_{HF} to account for header fastener strength increases. When the header consists of multiple wood components, such as multiple plies of the same wood type, the specific gravity of the critical component shall be used as specific gravity for the entire header. The critical component is the component onto which the hanger is directly mounted.

13.5.3.1 Test values shall be multiplied by the following factor, R_{HF} , to account for increased fastener perpendicular-to-grain strength used in the test:

$$R_{HF} = \frac{Z_{nominal}}{Z_{tested}} \leq 1.0 \quad (2)$$

13.5.4 *Header Adjustment-Top Mount Hangers*—Then test values shall be multiplied by the factor R_{HT} to account for header fastener and compression perpendicular-to-grain strength increases. When the header consists of multiple wood component, such as multiple plies of the same wood type, the specific gravity of the critical component shall be used as specific gravity for the entire header. For vertically oriented plies, the critical component is the component that contacts the vertical face of the hanger. For horizontally oriented plies, the critical component is the component that contacts the top flange of the hanger.

13.5.4.1 The adjustment to account for fastener and compression perpendicular-to-grain strength increases due to higher specific gravity(ies) shall be made by multiplying the ultimate test loads by the factor R_{HT} shown below:

$$R_{HT} = \frac{(0.5F_{c \perp \text{nominal}} A_{\text{header}} + Z_{\text{nominal}})}{(0.5F_{c \perp \text{tested}} A_{\text{header}} + Z_{\text{tested}})} \leq 1.0 \quad (3)$$

13.5.5 If an approved design standard (other than the AWC NDS) is used that does not provide calculated fastener values using material properties F_u , F_{yb} , and G , then Z_{tested} shall be the lower of the three following equations:

$$Z_{\text{tested}} = \frac{F_{u \text{ tested}}}{F_{u \text{ spec}}} \times Z_{\text{nominal}} \leq Z_{\text{nominal}} \quad (4)$$

$$Z_{\text{tested}} = \frac{F_{yb \text{ tested}}}{F_{yb \text{ nominal}}} \times Z_{\text{nominal}} \leq Z_{\text{nominal}} \quad (5)$$

$$Z_{\text{tested}} = \frac{G_{\text{tested}}}{G_{\text{nominal}}} \times Z_{\text{nominal}} \geq Z_{\text{nominal}} \quad (6)$$

13.5.6 Linear interpolation of test results between tested joist hanger fastener quantities shall be permitted for otherwise identical face-mount joist hangers with varying heights. Linear interpolation of test results between tested joist hanger widths shall be permitted. Other interpolation and extrapolation to other sizes shall not be permitted.

13.5.7 The design value determined in 13.3.1 shall be reduced by multiplying it by a steel ratio (R_s) as defined below.

$$R_s = \left(\frac{3.0}{2.5} \right) \left(\frac{F_{u \text{ spec}}}{F_{u \text{ tested}}} \right) \left(\frac{t_{\text{spec}}}{t_{\text{tested}}} \right) \leq 1.0 \quad (7)$$

13.5.8 For joist hanger test specimens tested at moisture contents less than the limit specified in Section 10, the resulting test loads shall be reduced by multiplying by R_{MC} .

$$R_{MC} = 1 - (MC_{\text{Limit}} - MC_{\text{test}}) \times 0.015 \leq 1.0 \quad (8)$$

13.5.9 If the compressive strength of the concrete or masonry as determined in 7.2 and used in the test exceeds the specified compressive strength of concrete, masonry, grout, or mortar to be used with that connector by more than 10 %, the allowable load as determined in 14.4.1 must be reduced by multiplying it by:

$$\sqrt{\frac{f_{c, \text{specified}}}{f_{c, \text{tested}}}} \leq 1.0 \text{ for concrete, or} \quad (9)$$

$$\sqrt{\frac{f_{m, \text{specified}}}{f_{m, \text{tested}}}} \leq 1.0 \text{ for masonry.} \quad (10)$$

No increase in design load is permitted if the measured compressive strength is less than the specified compressive strength.

13.6 Permitted Substitutions Without Adjustments:

13.6.1 *Fastener Size*—Load test results obtained from a joist hanger using one fastener size and quantity are applicable to the same joist hanger using a larger fastener size or quantity, provided the larger fastener does not cause splitting of the wood members and locations of existing fasteners are not changed.

13.6.2 *Top-Mount Hanger Depth*—Downward load test results from top-mount hangers shall be permitted to be applied without change to deeper but otherwise identical top-mount joist hangers.

13.6.3 *Hanger Seat Width*—Test results from top-mount and face-mount hangers shall be permitted to be applied without change to narrower seat width but otherwise identical hangers provided it can be shown that adequate joist support is present in the narrower configuration.

13.6.4 *Sawn Lumber Tests Extended to Sawn Lumber and Glulam Applications*—Load test results obtained from a joist hanger supporting a dimension lumber joist by dimension lumber headers are applicable to untested dimension lumber or structural glued laminated timber provided all of the following conditions are met: (1) the untested dimension lumber or glulam has a published specific gravity equal to or greater than the tested material, and (2) the untested dimension lumber or glulam headers have a net thickness equal to or greater than the tested headers.

13.6.5 *Sawn Lumber Tests Extended to Structural Composite Lumber Applications*—Load test results obtained from a joist hanger supporting a sawn lumber joist by sawn lumber headers are applicable to untested SCL provided all of the following conditions are met: (1) the untested SCL has published equivalent specific gravities for fastener performance in the relevant orientation(s) that equal or exceed the actual specific gravity of the sawn lumber material tested, and (2) the untested SCL headers have a net thickness equal to or greater than the tested headers.

13.6.6 *Sawn Lumber Flanged I-Joist Tests Extended to Alternative Applications*—Load test results obtained from a joist hanger supporting a wood I-joist on a wood I-joist header with sawn lumber flanges are applicable to untested wood materials of solid-sawn lumber, structural glued laminated timber, and structural composite lumber, and other wood I-joists provided all of the following conditions are met: (1) the untested sawn lumber and glulam materials have a published specific gravity equal to or greater than all of the specific gravities of the tested sawn lumber wood I-joist elements in contact with the hanger or its fasteners, (2) the untested structural composite lumber materials (structural composite lumber member or I-joist with structural composite lumber flanges) shall have a published equivalent specific gravity equal to or greater than all of the specific gravities of the tested sawn lumber wood I-joist elements in contact with the hanger or its fasteners, (3) the untested header material has a net thickness equal to or greater than the tested header I-joist flange, (4) the untested I-joist flanges shall have a thickness