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ACCEPTANCE CRITERIA FOR HOLD-DOWNS (TIE-DOWNS) ATTACHED TO WOOD MEMBERS

AC155

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PREFACE

Evaluation reports issued by ICC Evaluation Service, Inc. (ICC-ES), are based upon performance features of the International family of codes and other widely adopted code families, including the Uniform Codes, the BOCA National Codes, and the SBCCI Standard Codes. Section 104.11 of the *International Building Code*® reads as follows:

> The provisions of this code are not intended to prevent the installation of any materials or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

Similar provisions are contained in the Uniform Codes, the National Codes, and the Standard Codes.

This acceptance criteria has been issued to provide all interested parties with guidelines for demonstrating compliance with performance features of the applicable code(s) referenced in the acceptance criteria. The criteria was developed and adopted following public hearings conducted by the ICC-ES Evaluation Committee, and is effective on the date shown above. All reports issued or reissued on or after the effective date must comply with this criteria, while reports issued prior to this date may be in compliance with this criteria or with the previous edition. If the criteria is an updated version from the previous edition, a solid vertical line (|) in the margin within the criteria indicates a technical change, addition, or deletion from the previous edition. A deletion indicator (→) is provided in the margin where a paragraph has been deleted if the deletion involved a technical change. This criteria may be further revised as the need dictates.

ICC-ES may consider alternate criteria, provided the report applicant submits valid data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. Notwithstanding that a product, material, or type or method of construction meets the requirements of the criteria set forth in this document, or that it can be demonstrated that valid alternate criteria are equivalent to the criteria in this document and otherwise demonstrate compliance with the performance features of the codes, ICC-ES retains the right to refuse to issue or renew an evaluation report, if the product, material, or type or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use of the product, material, or type or method of construction.

Acceptance criteria are developed for use solely by ICC-ES for purposes of issuing ICC-ES evaluation reports.

ACCEPTANCE CRITERIA FOR HOLD-DOWNS (TIE-DOWNS) ATTACHED TO WOOD MEMBERS (AC155)

1.0 INTRODUCTION

1.1 Purpose: The purpose of this acceptance criteria is to establish requirements for hold-downs (tie-downs) attached to wood members to be recognized in an ICC Evaluation Service, Inc. (ICC-ES), evaluation report under the 2009 and 2006 *International Building Code*® (IBC), the 2009 and 2006 *International Residential Code*® (IRC), the BOCA® *National Building Code*/1999 (BNBC), the 1999 *Standard Building Code*© (SBC), and the 1997 *Uniform Building Code*™ (UBC). Bases of recognition are IBC Section 104.11, IRC Section R104.11, BNBC Section 106.4, SBC Section 103.7, and UBC Section 104.2.8.

1.2 Scope:

1.2.1 This criteria is applicable to hold-down (tie-down) devices and assemblies as defined in Sections 1.4.1 and 1.4.2, respectively. It provides methods to establish the following allowable loads, P_{all}, strength-level-factored resistance, P_s. and corresponding displacements, Δ_{all} and Δ_s, for hold-downs (tie-downs) based on Allowable Stress Design methods:

(a) Derivation of allowable loads and strength-level-factored resistances, P_{all} and P_s, and corresponding displacements, Δ_{all} and Δ_s, for nailed and screwed hold-down (tie-down) assemblies based on a combination of calculated strength characteristics and tests performed on a wood post.

(b) Derivation of allowable loads and strength-level-factored resistances, P_{all} and P_s, for bolted hold-down (tie-down) assemblies based on a combination of calculated strength characteristics and testing performed on both a steel jig and a wood post; and derivation of corresponding assembly displacements, Δ_{all} and Δ_s, based on testing on a wood post only.

(c) Derivation of allowable steel-strength loads for hold-down (tie-down) devices based on testing on a steel jig; and derivation of corresponding deformation characteristics of the device based on testing on a steel jig.

(d) (Optional): Derivation of allowable loads for hold-downs (tie-downs) based on prescriptive applications according to Section R602.10.3.2 of the IRC.

1.2.2 The following anchorage devices are outside the scope of this criteria:

1.2.2.1 Devices consisting of a structural steel strap with a bent end, where the bent end of the device is cast-in-place in concrete or masonry construction, or devices that are connected to wood members and installed partially embedded into concrete or masonry construction, such as cold-formed structural steel straps, die-stamped sill-plate connectors, or similar cold-formed or structural steel devices.

1.2.2.2 Continuous rod/cable holdown systems, with or without wood-shrinkage compensation devices.

1.2.2.3 Straight structural-steel straps installed to collect and transfer tension forces from their point of origin to load-resisting elements.

1.2.2.4 Hold-down devices that are designed to resist shear in addition to tension and compression forces.

1.3 Codes and Referenced Standards: Where standards are referenced in this criteria, the standards shall be applied consistently with the code (IBC or IRC) upon which compliance of the connector is based.

1.3.1 2009 and 2006 *International Building Code*® (IBC), International Code Council.

1.3.2 2009 and 2006 *International Residential Code*® (IRC), International Code Council.

1.3.3 BOCA® *National Building Code*/1999 (BNBC).

1.3.4 1999 *Standard Building Code*© (SBC).

1.3.5 1997 *Uniform Building Code*™ (UBC).

1.3.6 ANSI/AF&PA NDS-05, National Design Specification (NDS) for Wood Construction, 2005 edition with 2005 supplement, American Forest & Paper Association.

1.3.7 ANSI/ASME Standard B18.2.1-1996, Square and Hex Bolts and Screws, Inch Series; American Society of Mechanical Engineers.

1.3.8 ASCE/SEI 7-05, Minimum Design Loads for Buildings and Other Structures, including Supplements No. 1 and 2, excluding Chapter 14 and Appendix 11A, American Society of Civil Engineers/Structural Engineering Institute.

1.3.9 ASTM A 90-09, Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM International.

1.3.10 ASTM A 123-09 [-02 for the 2006 IBC], Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products, ASTM International.

1.3.11 ASTM A 924-07 [-04 for the 2006 IBC], Standard Specification for General Requirements for Steel Sheet, Metallic-coated by the Hot-Dip Process, ASTM International.

1.3.12 ASTM D 2395-07a$^{\varepsilon 1}$, Standard Test Method for Specific Gravity of Wood and Wood-Based Materials, ASTM International.

1.3.13 ASTM D 4442-07, Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials, ASTM International.

1.3.14 ASTM D 4444-08, Standard Test Methods for Use and Calibration of Hand Held Moisture Meters, ASTM International.

1.3.15 ASTM E 8-09, Standard Test Methods for Tension Testing of Metallic Materials, ASTM International.

1.3.16 ASTM F 606-09, Standard Test Method for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets, ASTM International.

1.3.17 ASTM F 1470-09, Standard Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection, ASTM International.

1.3.18 ASTM F 1575-03 (2008), Standard Test Method for Determining Bending Yield Moment of Nails, ASTM International.

1.3.19 ASTM F 1667-05 [-03 for the 2006 IBC], Standard Specification for Driven Fasteners: Nails, Spikes, and Staples, ASTM International.

1.4 Definitions:

1.4.1 Hold-down (Tie-down) Device: For purposes of this criteria, a hold-down (tie-down) device is the connector/bracket described in the approved quality control manual complying with the ICC-ES Acceptance Criteria for Quality Control Manuals (AC10) submitted by the evaluation report applicant.

1.4.2 Hold-down (Tie-down) Assembly: For purposes of this criteria, a hold-down (tie-down) assembly consists of the following components: (1) A hold-down (tie-down) device, (2) an anchor bolt/rod attached to the seat of the device, (3) a wood member, having specified dimensions and properties, (4) nails, bolts, or screws used to attach the hold-down (tie-down) device to the wood member, and (5) bearing plates or washers used to enhance the performance of the assembly. Figure 1 provides examples of a bolted hold-down (tie-down) assembly and a screwed or nailed hold-down (tie-down) assembly.

2.0 BASIC INFORMATION

2.1 General: The following information shall be submitted:

2.1.1 Product Description: Complete information pertaining to the hold-down (tie-down) device, including material specifications and drawn-to-scale production drawings showing all dimensions and tolerances, and the manufacturing process (including welds when applicable). Materials shall comply with recognized standards.

2.1.2 Installation Instructions: Installation details and drawings, noting installation requirements and/or limitations.

2.1.3 Packaging and Identification: A description of field identification of the hold-down (tie-down) device. Each device shall bear an imprint that clearly identifies the manufacturer (a registered trademark may serve as such identity), the model number, and the ICC-ES evaluation report number. Welded hold-down (tie-down) devices need not be identified with the name or logo of the inspection agency in accordance with Section 8.0 of the ICC-ES Rules of Procedure for Evaluation Reports.

2.2 Testing Laboratories: Testing laboratories shall comply with Section 2.0 of the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the ICC-ES Rules of Procedure for Evaluation Reports.

2.3 Test Reports: Test reports shall comply with AC85, and include the following:

2.3.1 A description of the tested hold-down (tie-down) assembly and device, including a drawing detailing all pertinent dimensions of the assembly and device. The description shall also include information concerning each component of the tested hold-down (tie-down) assemblies (refer to Section 1.4.2 of this criteria).

2.3.2 Actual dimensions, species, specific gravity, moisture content for each wood test specimen.

2.3.3 A description of any modifications made to the wood members used in hold-down (tie-down) assembly testing.

2.3.4 The measured steel physical properties of the hold-down (tie-down) device, including yield strength, tensile strength, and base-metal thickness.

2.3.5 A description of the fasteners, including the information required in Section 3.2.3 of this criteria.

2.3.6 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 outlined in Section 4.0 of this acceptance criteria. Additionally, photographs shall supplement the detailed drawings of the test setup and failure modes.

2.3.7 Individual and average load-versus-deformation curves, as plotted directly, or as reprinted from data acquisition systems.

2.3.8 Individual and average maximum test load values observed. Description of the nature, type and location of failure exhibited by each hold-down (tie-down) assembly or device tested, and a description of the general behavior of the test assembly or device during load application.

2.3.9 The sample size shall be in accordance with Section 4.2 of this criteria.

2.3.10 A description of the test method and loading procedure used, rate of loading, and time to maximum load.

2.3.11 The measured unbraced length of the anchor bolt/rod.

2.4 Product Sampling: Sampling shall comply with Section 3.1 of AC85 for welded hold-down (tie-down) devices. Sampling shall comply with Section 3.2 of AC85 for hold-down (tie-down) devices fabricated without welds.

3.0 TEST AND PERFORMANCE REQUIREMENTS

3.1 General:

3.1.1 Tension Testing:

3.1.1.1 Hold-down (tie-down) devices shall be tested such that a tension load is applied in reference to the intended application of the device when attached to a steel jig as described in Sections 4.1 (applicable subsections), 4.2.1, 4.3.1, 4.3.2, and 4.4 of this criteria. The devices shall be evaluated for an allowable steel-strength tension load capacity under Allowable Stress Design (ASD) and a strength-level factored resistance, along with corresponding displacement values in accordance with Section 3.4 of this criteria.

3.1.1.2 Hold-down (tie-down) assemblies shall be tested such that a tension load is applied in reference to the intended application of the assembly when attached to a wood member as described in Sections 4.1 (applicable subsections), 4.2.2, 4.3.1, 4.3.3, and 4.4 of this criteria. The assemblies shall be evaluated for an allowable tension load capacity under ASD and a strength-level factor resistance, along with corresponding displacement values in accordance with Section 3.5 of this criteria.

Exception: Strength-based allowable loads, P_{all}, and corresponding strength-level-factored resistances, P_s, for bolted hold-down (tie-down) assemblies shall be derived through testing on a steel jig in accordance with Sections 4.1, 4.2.1, 4.3.1, 4.3.2 and 4.4, and evaluation in accordance with Section 3.5.2. The bolted hold-downs

(tie-downs) must also be tested on a wood post, in order to derive values in accordance with Sections 3.5.3 and 3.5.5.

3.1.1.3 Hold-down (tie-down) assemblies may be tested and evaluated for an allowable uplift load capacity for use with alternate braced wall panels described in the first and second provisions of IRC Section R602.10.3.2. Testing shall comply with applicable requirements in Section 4.0 of this criteria, and assembly uplift capacity shall be evaluated in accordance with Section 3.6 of this criteria.

3.1.2 Compression Load Testing (Optional): At the option of the evaluation report applicant, the following compression load testing may be conducted:

3.1.2.1 Hold-down (tie-down) devices may be tested such that a compression load is applied in reference to the intended application of the device when attached to a steel jig as described in Sections 4.1, 4.2.1, 4.3.1, 4.3.2, and 4.4 of this criteria. The devices shall be evaluated for an allowable compression load capacity under ASD in accordance with Section 3.4 of this criteria.

3.1.2.2 Hold-down (tie-down) assemblies may be tested such that a compression load is applied in reference to the intended application of the assembly when attached to a wood member as described in Sections 4.1, 4.2.2, 4.3.1, 4.3.3, and 4.4 of this criteria. The assemblies shall be evaluated for an allowable compression load capacity under ASD in accordance with Section 3.5 of this criteria.

3.2 Test Materials:

3.2.1 Wood Materials:

3.2.1.1 All wood materials shall be solid-sawn lumber of structural quality with allowable values substantiated by accepted procedures, such as those referenced in Section 2303 of the IBC.

3.2.1.2 The specific gravity of the wood members used in hold-down (tie-down) assembly testing shall have a tested specific gravity, determined in accordance with ASTM D 2395, within 10 percent of the code specified value, and shall be reported on an oven-dry basis in accordance with ASTM D 2395. Specific gravity measurements taken at moisture contents other than oven-dry condition shall be adjusted to the oven-dry moisture content in accordance with Appendix X1 of ASTM D 2395.

3.2.1.3 The moisture content of the wood members shall be determined in accordance with ASTM D 4442 or D 4444.

3.2.2 Steel: The steel properties of the tested hold-down (tie-down) device, including yield point, tensile strength, and uncoated base-metal steel thickness shall be determined. Standard tensile tests of the steel from which the hold-down (tie-down) device was produced shall be conducted in accordance with ASTM E 8. Alternatively, the data are permitted to be obtained from the mill certification of the steel from which the hold-down (tie-down) device is manufactured. The uncoated base-metal thickness of the steel from which the tested hold-down (tie-down) device is formed shall be measured or calculated. When the base-metal thickness is calculated by converting the coating weight to a coating thickness and subtracting it from the overall measured thickness, coating weight tests shall be performed on the steel of the tested device in accordance with the requirements of ASTM A 90, ASTM A 924, or ASTM A 123. The following relationship is permitted to be used to estimate the coating thickness from the coating weight (mass): 1 oz/ft^2 coating weight = 1.7 mils coating thickness (7.14 g/m^2 coating mass = 1 µm coating thickness).

3.2.3 Fasteners: Fasteners from the same manufacturer's lot that are used in hold-down (tie-down) assembly testing shall be sampled in accordance with ASTM F 1470.

3.2.3.1 Bolts shall comply with ANSI/ASME Standard B18.2.1. Bolt tensile strength shall be derived using the procedures of ASTM F 606.

3.2.3.2 Anchor bolts/rods shall comply with a code referenced standard specification.

3.2.3.3 Nails shall comply with ASTM F 1667. Nail bending yield strength, F_{yb}, shall be derived using the procedures of ASTM F 1575, or the ICC-ES Acceptance Criteria for Nails and Spikes (AC116), as applicable.

3.2.3.4 Wood screws shall comply with either ANSI/ASME Standard B18.6.1 or the ICC-ES Acceptance Criteria for Alternate Dowel-Type Threaded Fasteners (AC233). Bending yield strength of the screws shall be derived using the procedures of Section 4.4 of AC233. Predrilled holes shall be a field requirement when wood screws are installed into predrilled holes for testing.

3.3 Adjustments to Test Results:

3.3.1 Strength Reduction Factor for Values Derived Through Testing on a Steel Jig: The steel tensile strength and base-metal thickness of hold-down (tie-down) devices tested on a steel jig shall be determined in accordance with Section 3.2.2 of this criteria. If the tensile strength or base-metal thickness, or both, of the steel from which the tested hold-down devices are formed exceed the specified values, the maximum tension or compression test loads of the devices shall be multiplied by the reduction factor, $R_{s(device)}$, as described in Section 3.4.1.1 of this criteria. This reduction factor also applies to allowable bolted hold-down (tie-down) assembly loads derived through testing on a steel jig. The strength reduction factor, $R_{s(device)}$, shall be calculated as follows:

$$\boldsymbol{R_{s(device)} = \left(\frac{F_{u-spec}}{F_{u-tested}}\right) \times \left(\frac{t_{spec}}{t_{tested}}\right) \leq 1.0}$$

where:

$R_{s(device)}$	=	Strength reduction factor for the hold-down device.
$F_{u\ -\ spec}$	=	Specified tensile steel strength of the hold-down device (ksi).
$F_{u\ -\ tested}$	=	Measured tensile strength steel of the hold-down device (ksi).
t_{spec}	=	Specified steel base-metal thickness of the hold-down device (inches).
t_{tested}	=	Measured steel base-metal thickness of the hold-down device (inches).

Additionally, if

$$\boldsymbol{0.95 \leq \left(\frac{t_{spec}}{t_{tested}}\right) \leq 1.05}$$

then,

$$\left(\frac{t_{spec}}{t_{tested}}\right) = 1.0$$

The tested steel tensile value shall not exceed the specified value by more than 20 percent.

3.3.2 Strength Reduction Factor for Hold-down (Tie-down) Assembly Values Derived Through Testing on a Wood Post: The steel tensile strength and base-metal thickness of hold-down (tie-down) devices used in assembly testing shall be determined in accordance with Section 3.2.2 of this criteria. If the tensile strength of the steel or the base-metal thickness, or both, from which the tested hold-down (tie-down) devices are formed exceed the specified values, the maximum tension or compression test load of the hold-down (tie-down) assembly shall be adjusted by a reduction factor, $R_{s(assembly)}$, as described in Section 3.5.1.1 of this criteria. The strength reduction factor, $R_{s(assembly)}$, shall be calculated as follows:

$$R_{s(assembly)} = \left(\frac{3.0}{2.5}\right) \times \left(\frac{F_{u-spec}}{F_{u-tested}}\right) \times \left(\frac{t_{spec}}{t_{tested}}\right) \leq 1.0$$

where:

$R_{s(assembly)}$ = Strength reduction factor for the hold-down (tie-down) device used in assembly testing.

$F_{u\ -\ spec}$ = Specified tensile steel strength of the hold-down (tie-down) device (ksi).

$F_{u\ -\ tested}$ = Measured tensile steel strength of the hold-down (tie-down) device (ksi).

t_{spec} = Specified tension tie or holdown steel base-metal thickness of the hold-down (tie-down) device (inches).

t_{tested} = Measured tension tie or holdown steel base-metal thickness of the hold-down (tie-down) device (inches).

Additionally, if

$$\mathbf{0.95} \leq \left(\frac{\boldsymbol{t_{spec}}}{\boldsymbol{t_{tested}}}\right) \leq \mathbf{1.05}$$

then,

$$\left(\frac{t_{spec}}{t_{tested}}\right) = 1.0$$

The tested steel tensile value shall not exceed the specified value by more than 20 percent.

3.3.3 Wood Specific Gravity Reduction Factor: The specific gravity of the wood members used in hold-down (tie-down) assembly testing shall be determined in accordance with Section 3.2.1 of this criteria. If the resulting specific gravity is greater than specified, the maximum tension or compression test load, as described in Section 3.5.1.1 of this criteria, shall be adjusted by a factor, R_{sg}, to account for an increase in fastener strength resulting from a higher actual specific gravity of the wood member used in testing. The wood specific gravity reduction factor shall be determined as follows:

$$\boldsymbol{R_{sg} = \left(\frac{Z_{spec}}{Z_{tested}}\right) \leq 1.0}$$

where:

R_{sg} = Wood specific gravity ratio reduction factor.

Z_{spec} = Sum of all the lateral fastener resistance values calculated according to the NDS equations and based on the following: (1) wood member material specified for the installation; (2) fastener quantity, type, and size specified for the installation; (3) published fastener bending yield strength, F_{yb}, values for screws or nails, or published steel tensile strength of the bolts, as applicable, used to attach the hold-down (tie-down) device to the wood member; and (4) specified steel tensile strength and thickness of the hold-down (tie-down) device specified for production in the approved quality control manual.

Z_{tested} = Sum of all the lateral fastener resistance values calculated according to the NDS equations and based on the following: (1) tested properties of the wood material; (2) fastener quantity, type, and measured size; (3) tested fastener bending yield strength, F_{yb}, value of the screws or nails, or tested steel tensile strength value of the bolts, as applicable, the wood member; and (4) tested steel tensile strength and thickness of the hold-down (tie-down) device.

3.4 Derivation of Allowable Tension (Mandatory) or Compression (Optional) Loads and Displacements for Hold-down (Tie-down) Devices: The allowable and strength-level-factored tension (mandatory) or compression (optional) loads for short-term load duration, such as wind/earthquake loads, of hold-down (tie-down) devices shall be limited to the lowest steel-strength allowable load, P_{all}, and corresponding strength-level-factored resistance, P_s, based on the criteria of Sections 3.4.1 and 3.4.2. The corresponding allowable displacement, Δ_{all}, and strength-level-response displacement, Δ_s, of the hold-down (tie-down) device shall be determined in accordance with Section 3.4.3.

3.4.1 Tested Strength Criterion for Derivation of Allowable Loads and Strength-level-factored Resistances for Hold-down (Tie-down) Devices:

3.4.1.1 A *tested strength-based* allowable load, P_{all}, shall be derived as follows: The lowest maximum tension (mandatory) or compression (optional) test load when the test sample size consists of three hold-down (tie-down) devices, or the average maximum tension or compression test load when the test sample size consists of six hold-down (tie-down) devices, shall be multiplied by the reduction factor, $R_{s(device)}$ (when applicable), and divided by a safety factor equal to 2.5:

$$P_{all} = \left(\frac{Test\ Value \times R_{s(device)}}{2.5}\right)$$

3.4.1.2 The corresponding strength-level-factored resistance, P_s, shall be determined by multiplying the allowable steel-strength load, P_{all}, determined according to Section 3.4.1.1, by 1.4:

$$P_s = P_{all} \times 1.4$$

Where P_s shall represent a factored resistance ($\varphi \times P_s$, where $\varphi = 1.0$).

3.4.2 Tested Displacement Criterion for Derivation of Allowable Loads and Strength-level-factored Resistances for Hold-down (Tie-down) Devices:

3.4.2.1 From the average load-displacement curve of all tested hold-down (tie-down) devices, the tested displacement-based strength-level-factored resistance, P_s, corresponding to a maximum permitted strength-level-response displacement, Δ_s, equal to 0.185 inch (4.7 mm) shall be recorded. Refer to Figure 4.

3.4.2.2 A tested displacement-based allowable steel-strength load, P_{all}, shall be derived by dividing the strength-level-factored resistance, P_s, from Section 3.4.2.1 by 1.4:

$$P_{all} = \frac{P_s}{1.4}$$

3.4.3 Derivation of Corresponding Displacements for Hold-down (Tie-down) Devices: The allowable and strength-level-response displacements, Δ_{all} and Δ_s, corresponding to the lowest applicable loads determined in accordance with Sections 3.4.1 and 3.4.2, shall be determined from the average load-displacement curve of the steel-jig-tested hold-down (tie-down) devices. In cases where the lowest applicable loads are governed by the displacement criterion of Section 3.4.2, the strength-level-response displacement, Δ_s, is 0.185 inch (4.7 mm). Refer to Figure 4.

3.5 Derivation of Allowable Tension (Mandatory) or Compression (Optional) Loads and Displacements for Hold-down (Tie-down) Assemblies: The allowable and strength-level-factored tension (mandatory) or compression (optional) loads for short-term load duration, such as wind/earthquake loads, of hold-down (tie-down) assemblies shall be limited to the lowest allowable load, P_{all}, and corresponding strength-level-factored resistance, P_s, based on the criteria of Sections 3.5.1, 3.5.3 and 3.5.4. The corresponding allowable displacement, Δ_{all}, and strength-level-response displacement, Δ_s, of the hold-down (tie-down) assembly shall be determined in accordance with Section 3.5.5.

Exception: For bolted hold-down assemblies, the criterion of Section 3.5.2 shall be used in lieu of the criterion of Section 3.5.1, for the purpose of determining the lowest allowable load, P_{all}, and corresponding strength-level-factored resistance, P_s. The tested displacement criterion of Section 3.5.3 and the calculated strength criterion of Section 3.5.4 shall also be taken into consideration in determining the lowest allowable load, P_{all}, and corresponding strength-level-factored resistance, P_s. The corresponding displacement values for the bolted hold-down (tie-down) assemblies shall be based on the criterion of Section 3.5.5.

3.5.1 Tested Strength Criterion for Derivation of Allowable Loads and Strength-level-factored Resistances for Nailed and Screwed Hold-down (Tie-down) Assemblies:

3.5.1.1 For nailed and screwed hold-down (tie-down) assemblies, the tested strength-based allowable load, P_{all}, shall be derived from tests performed on a wood post as follows: The lowest maximum tension (mandatory) or compression (optional) test load when the test sample size consists of three hold-down (tie-down) assemblies, or the average maximum tension or compression test load when the test sample size consists of six hold-down (tie-down) assemblies, shall be multiplied by the steel-strength reduction factor, $R_{s(assembly)}$ (when applicable), or the wood specific gravity ratio reduction factor, R_{sg} (when applicable), whichever results in the greatest reduction; and divided by a safety factor equal to 3.0:

$$P_{all} = \left(\frac{Test\ Value \times R_{s(assembly)}}{3.0}\right)$$

Or

$$P_{all} = \left(\frac{Test\ Value \times R_{sg}}{3.0}\right)$$

whichever is less.

3.5.1.2 The corresponding strength-level-factored resistance, P_s, shall be determined by multiplying the allowable load, P_{all}, from Section 3.5.1.1 by 1.4:

$$P_s = P_{all} \times 1.4$$

Where P_s shall represent a factored resistance ($\varphi \times P_s$, where $\varphi = 1.0$).

3.5.2 Tested Strength Criterion for Derivation of Allowable Loads and Strength-level-factored Resistances for Bolted Hold-down (Tie-down) Assemblies:

3.5.2.1 For bolted hold-downs (tie-downs), a tested strength-based allowable assembly load, P_{all}, shall be derived from tests performed on a steel jig as follows: The lowest maximum tension (mandatory) or compression (optional) test load when the test sample size consists of three hold-downs (tie-downs), or the average maximum tension or compression test load when the test sample size consists of six hold-downs (tie-downs), shall be multiplied by the strength reduction factor, $R_{s(device)}$ (when applicable), and divided by a safety factor equal to 2.5:

$$P_{all} = \left(\frac{Test\ Value \times R_{s(device)}}{2.5}\right)$$

3.5.2.2 The corresponding strength-level-factored resistance, P_s, shall be determined by multiplying the allowable load, P_{all}, from Section 3.5.2.1 by 1.4:

$$P_s = P_{all} \times 1.4$$

Where P_s shall represent a factored resistance ($\varphi \times P_s$, where $\varphi = 1.0$).

3.5.3 Tested Displacement Criterion for Derivation of Allowable Loads and Strength-level-factored Resistances for Nailed, Screwed, and Bolted Hold-down (Tie-down) Assemblies:

3.5.3.1 From the average load-displacement curve of all tested hold-down (tie-down) assemblies tested on a

wood post, the tested displacement-based strength-level-factored resistance, P_s, corresponding to a maximum strength-level-response displacement, Δ_s, equal to 0.250 inch (6.4 mm) shall be recorded. Refer to Figure 4.

3.5.3.2 A tested displacement-based allowable load, P_{all}, for the hold-down (tie-down assembly shall be derived by dividing the strength-level-factored resistance, P_s, from Section 3.5.3.1 by 1.4:

$$P_{all} = \frac{P_s}{1.4}$$

3.5.4 Calculated Strength Criterion: A calculated strength-based allowable load, P_{all}, for nailed, screwed, and bolted hold-down (tie-down) assemblies shall equal the sum of the allowable fastener lateral resistance values of the nails, screws, and bolts used to attach the hold-down (tie-down) device to the wood post. The corresponding strength-level-factored resistance, P_s, shall be taken as 1.4 times the allowable load, P_{all}, calculated in accordance with the NDS.

3.5.4.1 Allowable and strength-level-factored fastener resistance values shall be determined in accordance with the NDS and shall consider the following: (1) cross-sectional area and specific gravity of the wood member attached to the hold-down (tie-down) device; (2) fastener quantity, type, and size specified for the installation; (3) published bending yield strength, F_{yb}, value of screws or nails, or published steel tensile strength of bolts, as applicable, specified for screws, nails, or bolts used to attach the device to the wood post; (4) hold-down (tie-down) device steel tensile strength value specified for production in the approved quality control manual, and (5) applicable adjustment factors specified in NDS.

3.5.4.2 For bolted hold-down (tie-down) assemblies, wood failure or tear-out along a row of bolts caused by local stresses at the wood member net section shall be calculated. Calculations based on methods presented in Appendix E (Local Stresses in Fastener Groups) of the NDS, shall satisfy this requirement.

3.5.4.3 Hold-down (tie-down) assemblies shall not be permitted to be rated for an allowable compression load that is cumulative with the bearing capacity of wood members.

3.5.5 Derivation of Corresponding Hold-down (Tie-down) Assembly Displacements: For all nailed, screwed and bolted hold-down assemblies, the allowable and strength-level-response displacements, Δ_{all} and Δ_s, corresponding to the lowest applicable allowable load and strength-level-factored resistance, P_{all} and P_s, determined in accordance with Sections 3.5.1 through 3.5.4, shall be determined from the average load-displacement curve of the hold-down (tie-down) assembly tests performed on a wood post. In cases where the lowest applicable loads are governed by the displacement criterion of Section 3.5.3, the strength-level-response displacement, Δ_s, is 0.250 inch (6.4 mm). Refer to Figure 4.

3.6 (Optional) Derivation of Allowable Uplift Capacities for Hold-down (Tie-down) Assemblies Complying with the IRC: The provisions of this section are applicable when requesting evaluation of a hold-down (tie-down) for compliance with IRC Section R602.10.3.2 as a tie-down device. The allowable uplift load for short-term load duration, such as wind/earthquake loads, of the tie-down assembly shall be limited to the lowest allowable load, P_{all}, based on the criteria of Sections 3.6.1 through 3.6.3:

3.6.1 Tested Strength Criterion: An allowable uplift load, P_{all}, based on the strength of the tie-down assembly shall be derived in accordance with Section 3.5.1 or Section 3.5.2 of this criteria, as applicable, and shall not be less than that required by IRC Section R602.10.3.2, depending on the application.

3.6.2 Tested Displacement Criterion: An allowable uplift load, P_{all}, based on a strength-level-response displacement limitation shall be derived in accordance with Section 3.5.3 of this criteria.

3.6.3 Calculated Strength Criterion: An allowable uplift load, P_{all}, based on the lowest calculated strength of the following components of the tie-down assembly:

3.6.3.1 Allowable capacity of fasteners used to attach the tie-down device to the wood member shall be derived in accordance with Section 3.5.4 of this criteria.

3.6.3.2 Allowable capacity of the end studs of the prescribed alternate braced-wall panel attached to the tie-down device.

3.6.3.3 Allowable capacity of the cast-in-place anchor bolt/rod used to connect the tie-down device to a normal-weight concrete spread footing according to accepted engineering principles.

4.0 TEST METHODS

4.1 Apparatus:

4.1.1 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 Method ASTM E 4, shall be used.

4.1.2 Displacement Gauge: All tests shall use dial gauges or linear variable displacement transformers (LVDTs), having a least reading of 0.001 inch (0.025 mm).

4.1.2.1 When testing hold-down (tie-down) devices on a steel jig, the displacement gauge shall measure the relative movement between the hold-down (tie-down) device and the steel test jig. Displacement shall be measured between the top of the anchor bolt/rod attached at the seat of the device and a stable reference point on the steel jig just beyond the device. Placement of the dial gauges or LVDTs shall ensure accurate measurement of the deformation of hold-down (tie-down) device. Refer to Figure 2.

4.1.2.2 When testing hold-down (tie-down) assemblies on wood posts, the displacement gauge shall measure the relative movement between the wood post and the test bed. Displacement shall be measured between the wood post and a stable reference point on the test bed where the anchor bolt/rod is attached. Placement of the dial gauges or LVDTs shall ensure accurate measurement of the assembly displacement that includes deformation and rotation of the body of the hold-down (tie-down) device, slip between the device and the post, and fastener slip (and anchor bolt/rod elongation, when applicable). Refer to Figure 3.

4.2 Test Sample Size:

4.2.1 Hold-down (Tie-down) Device Testing:

4.2.1.1 Differences in hold-down (tie-down) device size, configuration, and material specifications shall be the basis for establishing a test sample size.

4.2.1.2 A minimum of three hold-down (tie-down) devices for each type of device (size, configuration, and material specifications) shall be tested on a steel jig.

4.2.1.3 If the maximum test load for a tested device varies by more than 20 percent from the average, testing shall be conducted on three additional hold-down (tie-down) devices.

4.2.2 Hold-down (Tie-down) Assembly Testing:

4.2.2.1 Differences in assembly configuration and component specifications (refer to Section 1.4.2) shall be the basis for establishing a test sample size.

4.2.2.2 A minimum of three hold-down (tie-down) assemblies shall be tested on wood posts for each selected combination of variables affecting the hold-down (tie-down) assembly performance.

4.2.2.3 If the maximum test load for a tested assembly varies by more than 20 percent from the average, testing shall be conducted on three additional hold-down (tie-down) assemblies.

4.3 Test Setup:

4.3.1 General:

4.3.1.1 Hold-down (tie-down) devices and assemblies shall be tested individually in such a manner to simulate the essential function of the hold-down (tie-down) device or assembly. Test loads shall be applied with reference to the intended end-use application of the hold-down (tie-down) device or assembly. Low-friction rollers are permitted to be used in the test setup to prevent lateral movement of the steel jig or wood post due to eccentricity.

4.3.1.2 The anchor bolt/rod, which is attached to the seat of the hold-down (tie-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 (tie-down) device and attached to the device with a nut and washer in accordance with the end-use application (manufacturer's installation instructions).

4.3.1.3 When testing bolted hold-down (tie-down) devices or assemblies, the nuts used with the bolts to the steel jig or wood post shall be at most finger tight, to remove the effects of clamping.

4.3.2 Hold-down (Tie-down) Device Testing on a Steel Jig:

4.3.2.1 When testing bolted hold-down (tie-down) devices, the bolt threads shall be excluded from the shear plane between the device and the steel jig.

4.3.2.2 To minimize friction forces between the hold-down (tie-down) device and the steel jig, a low friction material such as Teflon® or polyethylene shall be inserted between the device and steel jig before load testing.

4.3.3 Hold-down (Tie-down) Assembly Testing:

4.3.3.1 Bolted hold-down (tie-down) assembly testing shall only require the application of load up to the strength-level-factored resistance, P_s, as determined in Section 3.5.3 of this criteria.

4.3.3.2 Wood test members shall be conditioned to reach equilibrium with a moisture content of 11 to 19 percent when the hold-down (tie-down) assemblies are tested for dry in-service conditions. When the assemblies are tested for wet in-service conditions, wood test members shall be conditioned to an equilibrium moisture content greater than 19 percent. Refer to Section 3.2.1 of this criteria for details on measuring wood moisture content.

4.3.3.3 For hold-down (tie-down) assemblies evaluated in accordance with Sections 3.5 or 3.6 of this criteria, the test setup shall consist of the wood member specified for use with the hold-down (tie-down) device; fasteners specified for attaching the device to the wood post; and for tension load testing, an anchor bolt/rod having a minimum length of 1 inch (25.4 mm), measured from the seat of the hold-down (tie-down) device to the test bed. For optional compression load testing, the maximum unbraced length of the test anchor bolt/rod intended for use with hold-down (tie-down) assembly shall be as specified by the evaluation report applicant.

4.3.3.4 Installation of the hold-down (tie-down) device to the wood post shall maintain fastener end and edge distances as expected in field conditions, with minimum distances complying with the NDS, where applicable.

4.4 Test Procedure

4.4.1 Preloading: An initial load, or preload, shall not be applied for tension (uplift) load or compression load (optional) testing of hold-down (tie-down) devices or assemblies. The prohibition on applying a preload is based upon the premise that these devices are designed and installed to resist short-term loading, such as wind or seismic loads, where no settling of the installed device, induced by the wind or seismic forces, occurs in the loading direction prior to the application of the wind or seismic design loads.

4.4.2 Test Load Application and Recording: The test load shall be applied at a uniform crosshead rate between 0.03 and 0.20 inch (0.8 to 5.1 mm) per minute until failure or maximum load. Loads shall be recorded to a precision of 1 percent during application of test loads.

4.4.3 Displacement Recording: The displacements shall be recorded to the nearest 0.001 inch (0.025 mm), and a sufficient number of readings shall be taken to permit determining the load at strength-level-response displacement, Δ_s, limits of 0.250 inch (6.3 mm) for hold-down (tie-down) assembly testing on a wood post and of 0.185 inch (4.7 mm) for hold-down (tie-down) device testing on a steel jig.

5.0 QUALITY CONTROL

5.1 Welded hold-down (tie-down) devices shall be manufactured under an approved quality control program with inspections by an inspection agency accredited by the International Accreditation Service (IAS) or otherwise acceptable to ICC-ES. Third-party follow-up inspections are not required under this acceptance criteria for non-welded hold-down (tie-down) devices.

5.2 A quality control manual complying with the ICC-ES Acceptance Criteria for Quality Control Manuals (AC10) shall be submitted.

6.0 EVALUATION REPORT RECOGNITION

6.1 General: The evaluation report shall describe the hold-down (tie-down) device with respect to material specifications.

6.2 Engineered Applications of Hold-down (Tie-down) Devices and Assemblies: The evaluation report shall provide a table specifying the following information:

6.2.1 Hold-down (tie-down) device dimensions.

6.2.2 Required fasteners, including type, number, size, for attaching the hold-down (tie-down) device to the wood member. Additionally, a note indicating whether predrilled holes are required.

6.2.3 Allowable steel-strength load, P_{all}, of the hold-down (tie-down) device determined in accordance with Section 3.4 of this criteria, with the following footnoted information:

6.2.3.1 A statement indicating that the allowable load values of the hold-down (tie-down) device are a measure of steel strength of the device when tested on a steel jig with a safety factor of 2.5 applied to the (lowest or average, whichever is applicable) maximum test load.

6.2.3.2 A statement indicating that the allowable strength values are applicable for designs complying with Sections 12.10 and 12.11.2 of ASCE 7, or Sections 1633.2.8 through 1633.2.9 of the UBC, as applicable.

6.2.3.3 A statement similar to the one specified in Section 6.2.5.3 of this criteria.

6.2.4 Displacement at allowable load, Δ_{all}, and displacement at strength-level-response load, Δ_s, for the hold-down (tie-down) device, determined in accordance with Section 3.4 of this criteria, with the following footnoted information: A statement indicating that the tabulated displacement consists only of deformation of the hold-down (tie-down) device when tested on a steel jig, and that other variables contributing to total displacement, d_a, such as fastener slip, wood shrinkage, and anchor bolt/rod elongation, shall be checked by the registered design professional.

6.2.5 The lowest of the allowable loads, or at the option of the evaluation report applicant, all of the allowable loads, P_{all}, of the hold-down (tie-down) assembly, determined in accordance with Section 3.5 of this criteria, with the following footnoted information:

6.2.5.1 A statement indicating that the assembly shall have an allowable strength equal to or exceeding the required strength of the assembly under the action of the ASD (Allowable Stress Design) load combinations referenced in the applicable code.

6.2.5.2 A statement indicating which adjustment factors from the NDS are included in the derivation of the tabulated allowable load, P_{all}.

6.2.5.3 The following statement: "When using the basic load combinations in accordance with IBC Section 1605.3.1 (or UBC Section 1612.3.1), the tabulated allowable loads for the hold-down (tie-down) shall not be increased for wind or earthquake loading. When using the alternate basic load combinations in IBC Section 1605.3.2 (or UBC Section 1612.3.2) that include wind or earthquake loads, the tabulated allowable loads for the hold-down (tie-down) shall not be increased by $33^1/_3$ percent, nor shall the alternative basic load combinations be reduced by a factor of 0.75."

6.2.6 Displacement at allowable load, Δ_{all}, and displacement at strength-level-factored resistance, Δ_s, for the hold-down (tie-down) assembly, determined in accordance with Section 3.5.5, with the following footnoted information:

6.2.6.1 A statement indicating that the tabulated displacement consists of deformation and rotation of the hold-down (tie-down), and fastener slip of (bolts, screws, nails, as applicable) used to attach the hold-down (tie-down) to the wood member.

6.2.6.2 Sufficient detail to permit the end user of the evaluation report to derive the total displacement of the hold-down (tie-down) assembly including shrinkage of supporting wood members and anchor bolt/rod elongation, when applicable.

6.2.6.3 A statement alerting the report user to the fact that design of hold-downs used in series shall account for the cumulative deformation of all hold-downs (tie-downs) within said series.

6.3 Prescriptive Applications of Tie-down Devices According to the IRC (Optional): For tie-down assemblies complying with Section 3.6 of this criteria, the evaluation report shall include the following information:

6.3.1 Tie-down device dimensions, and required fasteners, including type, number, size, for attaching the tie-down device to the wood member. Additionally, a note indicating whether predrilled holes are required.

6.3.2 Details concerning the alternate braced wall panel's vertical boundary members, such as minimum specific gravity and nominal dimensions.

6.3.3 An allowable uplift load, P_{all}, of the tie-down assembly, which shall not be less than that required by IRC Section R602.10.3.2, depending on the application.

6.3.4 A figure, drawn to scale, showing the complete tie-down assembly, including details on the concrete spread footing, anchorage to the concrete footing, and attachment of the tie-down device to the boundary members of the alternate braced-wall panel. The figure shall have sufficient detail and information such that the building official may use the evaluation report to verify compliance with Section R602.10.3.2 of the IRC and waive the requirement of submission of construction documents and other data according to Section R106.1 of the IRC.

6.4 Design: The evaluation report shall include a section entitled "Design" and include the following statements:

6.4.1 The design of wood members fastened to (*model name or number*) hold-down (tie-down) device(s) shall consider combined stresses as follows:

- Single shear: The wood member shall be checked for its allowable capacity at the critical net section for total combined stresses in accordance with the NDS, where applicable. Total combined stresses at the critical net section shall consider combined flexural bending due to hold-down (tie-down) eccentricity relative to the centroid

of the connected wood member (M_{xx} and M_{yy}), and tension (T).

- Double shear: The wood member shall be checked for its allowable capacity at the critical net section for total combined stresses in accordance with the NDS, where applicable. Total combined stresses at the critical net section shall consider flexural bending due to hold-down (tie-down) eccentricity relative to the centroid of the connected wood member (M_{xx} or M_{yy}), and tension (T).

6.5 Conditions of Use: The evaluation report shall include the following Conditions of Use:

6.5.1 The use of hold-downs (tie-downs) in contact with chemically treated preservative wood is subject to the approval of the code official, since the effects of corrosion of metal in contact with chemically treated wood on the structural performance of the devices is outside the scope of this report.

6.5.2 No further duration of load increase for wind or earthquake loading shall be allowed.

6.5.3 Drawings and design details verifying compliance with this report shall be submitted to the code official for approval. The drawings and calculations shall be prepared by a registered design professional when required by the statutes of the jurisdiction in which the project is to be constructed.

6.6 For compliance with the 2009 IBC, a statement of special inspection shall be prepared by the registered design professional in responsible charge, and submitted to the code official for approval, where required by Section 1705 of the 2009 IBC. For compliance with the 2006 IBC, a quality assurance plan shall be submitted to the code official for approval, where required by Sections 1705 or 1706 of the 2006 IBC.

6.7 Special inspections for seismic resistance shall be conducted as required, and in accordance with the appropriate section(s) of Chapter 17 of the IBC.

6.8 Special inspections for anchor bolts in concrete or masonry shall be conducted in accordance with Section 1704.4 or 1704.5 of the IBC or Sections 1701.5.1 or 1701.5.7 of the UBC. ■

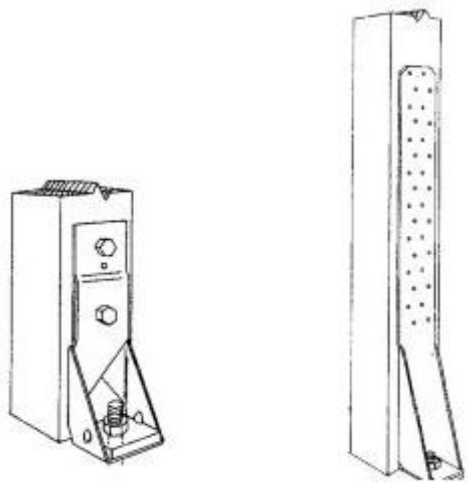

FIGURE 1—ILLUSTRATIONS OF A BOLTED HOLD-DOWN (TIE-DOWN) ASSEMBLY (LEFT FIGURE) AND A SCREWED OR NAILED HOLD-DOWN (TIE-DOWN) ASSEMBLY (RIGHT FIGURE)

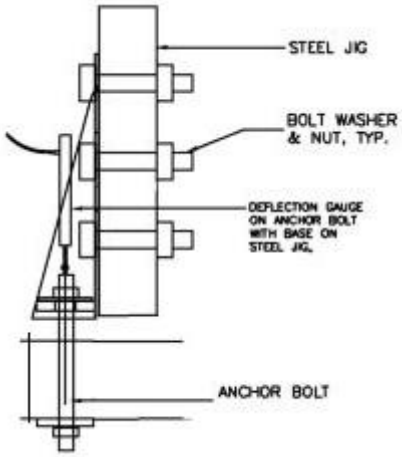

FIGURE 2—TENSION LOAD TEST SETUP FOR A SINGLE HOLD-DOWN (TIE-DOWN) DEVICE SHOWING LOCATION OF DEFLECTION GAUGE ON ANCHOR BOLT WITH BASE ON STEEL JIG (LOAD APPLICATION, LATERAL RESTRAINTS, AND TEST BED NOT SHOWN, FOR CLARITY; REFER TO FIGURE 3 FOR DETAILS)

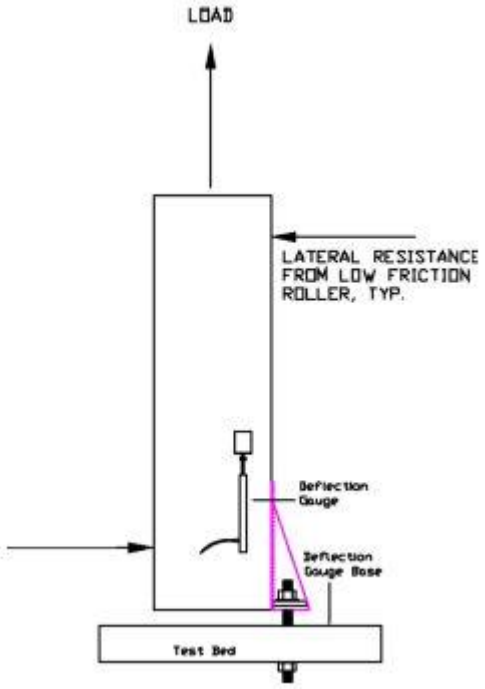

FIGURE 3—TENSION LOAD TEST SETUP FOR A SINGLE HOLD-DOWN (TIE-DOWN) ASSEMBLY SHOWING THE LOCATION OF THE DEFLECTION GAUGE ON THE WOOD POST WITH THE GAUGE BASE ON THE TEST BED WHERE THE ANCHOR BOLT/ROD IS ATTACHED (NOT TO SCALE)

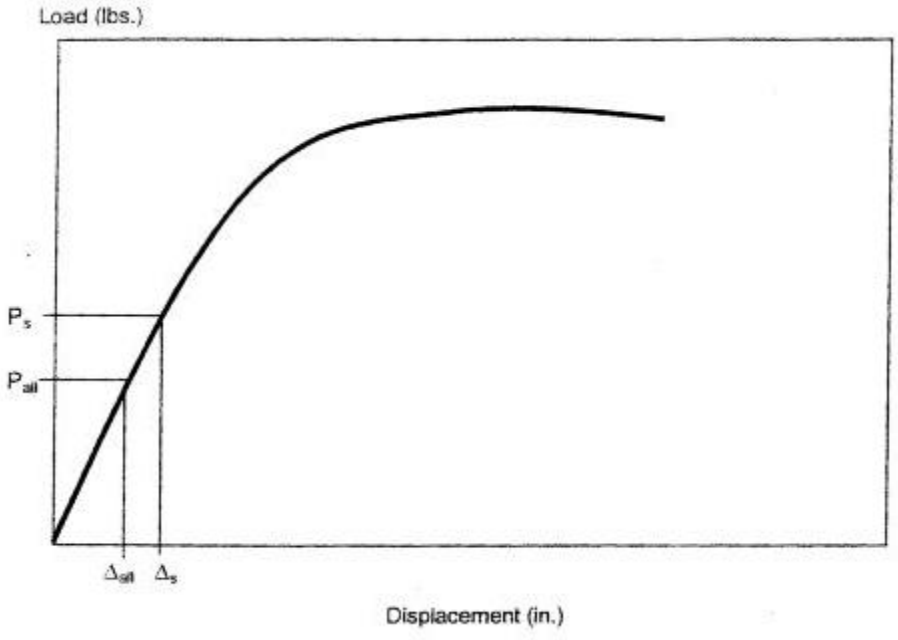

FIGURE 4—LOAD-DISPLACEMENT CURVE FOR TESTED HOLD-DOWN (TIE-DOWN) ASSEMBLIES OR DEVICES, ILLUSTRATING THE RELATIONSHIP BETWEEN:

- **Allowable Displacement, Δ_{all}, at Allowable Load, P_{all}.**
- **Strength-level Response Displacement, Δ_s, at the Strength-level Factored Resistance, P_s.**

where:

$P_{all} \leq$ **Tested maximum load ÷ safety factor.**
$P_s =$ $1.4 \times P_{all}$
$\Delta_s \leq$ **0.250 inch (6.4 mm) for hold-down (tie-down) assembly testing on a wood post.**
$\Delta_s \leq$ **0.185 inch (4.7 mm) for hold-down (tie-down) device testing on a steel jig.**