



June 6, 2008

**TO: PARTIES INTERESTED IN CAST-IN-PLACE COLD-FORMED STEEL CONNECTORS IN CONCRETE FOR LIGHT-FRAME CONSTRUCTION**

**SUBJECT: Proposed Acceptance Criteria for Cast-in-place Cold-formed Steel Connectors in Concrete for Light-frame Construction, Subject AC398-0608-R2 (PB/BG)**

Dear Madam or Sir:

The subject acceptance criteria was discussed at the May 30, 2008, Evaluation Committee hearing. At the hearing, staff presented an acceptance criteria draft that was substantially different from the one posted on the ICC-ES web site prior to the meeting. There were several people who requested additional time to review the proposal in detail. Consequently, the attached proposed acceptance criteria is posted on the June 2008 alternate agenda for those parties interested in providing technical comments to staff. Staff will revise the criteria based on comments received and submit it to the Evaluation Committee for approval either by ballot under the alternate criteria agenda process or at a future Evaluation Committee meeting. Comments received will be posted on the web site shortly after the close of the comment period.

You are cordially invited to submit written comments, within 30 days of the date of this letter. An explanation of the alternate criteria process can be found on our web site at [http://www.icc-es.org/Criteria\\_Development/alternative\\_criteria\\_process.shtml](http://www.icc-es.org/Criteria_Development/alternative_criteria_process.shtml).

Your cooperation is requested in forwarding to the Los Angeles business/regional office all material directed to the Evaluation Committee. Parties interested in the deliberations of the committee should refrain from communicating, whether in writing or verbally, with committee members. The committee reserves the right to refuse communications that do not comply with this request.

Newly approved acceptance criteria may involve test methods or test protocols that are not currently included in the scope of testing services offered by accredited testing laboratories. As noted in the ICC-ES Rules of Procedure for Evaluation Reports, the scope of the laboratory's accreditation must include the type of testing that is to be reported to ICC-ES. We encourage accredited laboratories to expand their scopes of accreditation to include testing under newly approved acceptance criteria. Please note that testing laboratories must be accredited by the International Accreditation Service (IAS) or by another accreditation body that is a signatory to the International Laboratory

Accreditation Cooperation Mutual Recognition Arrangement. For further information, please contact IAS at (562) 699-0541, extension 3309, or send an e-mail to [pmccullen@iasonline.org](mailto:pmccullen@iasonline.org).

If you have any questions, please contact the undersigned at (800) 423-6587, extension 3306. You may also reach us by e-mail at [es@icc-es.org](mailto:es@icc-es.org).

Yours very truly,

A handwritten signature in black ink, appearing to read "Peter Bahlo". The signature is written in a cursive style with a large initial "P".

Peter Bahlo, P.E.  
Senior Staff Engineer

PB/raf

Enclosure

cc: Evaluation Committee



## PROPOSED ACCEPTANCE CRITERIA FOR CAST-IN-PLACE COLD-FORMED STEEL CONNECTORS IN CONCRETE FOR LIGHT-FRAME CONSTRUCTION

AC398

Proposed June 2008

### 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*<sup>®</sup> 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.

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 proposed in this document, and otherwise meet the applicable performance requirements of the codes. Notwithstanding that a product, material, or type or method of construction meets the requirements of the criteria proposed in this document, or that it can be demonstrated that valid alternate criteria are equivalent to the criteria in this document and otherwise meet the applicable performance requirements 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 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 for purposes of issuing ICC-ES evaluation reports.*

## PROPOSED ACCEPTANCE CRITERIA FOR CAST-IN-PLACE COLD-FORMED STEEL CONNECTORS IN CONCRETE FOR LIGHT-FRAME CONSTRUCTION

### 1 1.0 INTRODUCTION

2 1.1 **Purpose:** The purpose of this criteria is to establish requirements for ICC  
3 Evaluation Service, Inc. (ICC-ES), recognition of cast-in-place cold-formed steel  
4 connectors in concrete under Sections 1911, 1912, and 2303.5 of the 2006 *International*  
5 *Building Code*<sup>®</sup> (IBC), and Section R104.11 of the 2006 *International Residential Code*<sup>®</sup>  
6 (IRC).

7 The reason for the development of this criteria is the absence of reference  
8 standards in the IBC that can be used to establish the code compliance of cast-in-place  
9 cold-formed steel connectors used as anchorage to concrete for light-frame construction.

### 10 1.2 Scope:

11 1.2.1 The provisions of this criteria shall be used to derive the capacity of  
12 cold-formed steel connectors cast in concrete for purposes of transmitting loads from  
13 attached wood or cold-formed steel members (e.g., joists, ties, plates, tracks, posts, and  
14 studs) or receiving loads from concrete members.

15 1.2.2 The provisions of this criteria shall be used to establish the capacities  
16 of cold-formed steel connectors based on Allowable Stress Design (ASD) methods, where  
17 ASD loads are derived considering measured (tested) and calculated strength  
18 characteristics, and measured (tested) displacement characteristics.

19 1.2.3 The provisions of this criteria shall be applicable only to the  
20 cold-formed steel connectors as defined in Section 1.4.2 of this criteria.

### 21 1.3 Codes and Referenced Standards:

22 1.3.1 2006 *International Building Code*<sup>®</sup>, International Code Council.

- 23                   **1.3.2** 2006 *International Residential Code*<sup>®</sup>, International Code Council.
- 24                   **1.3.3** ACI 355.2-04, Qualification of Post-Installed Mechanical Anchors in  
25 Concrete and Commentary, American Concrete Institute.
- 26                   **1.3.4** AISI (2001), North American Specification for the Design of  
27 Cold-formed Steel Structural Members (AISI-NAS) with Appendix A, including 2004  
28 Supplement; American Iron and Steel Institute.
- 29                   **1.3.5** AISI TS-3-02, Standard Methods for Determination of Uniform and  
30 Local Ductility, American Iron and Steel Institute.
- 31                   **1.3.6** AISI TS-5-02, Test Methods for Mechanically Fastened Cold-Formed  
32 Steel Connections, American Iron and Steel Institute.
- 33                   **1.3.7** ANSI/AF&PA (2005) National Design Specification for Wood  
34 Construction (NDS) and Supplement, American Forest & Paper Association.
- 35                   **1.3.8** ANSI/ASME Standard B18.2.1-1996, Square and Hex Bolts and  
36 Screws, Inch Series; American Society of Mechanical Engineers.
- 37                   **1.3.9** ASCE/SEI 7-05, Minimum Design Loads for Buildings and Other  
38 Structures including Supplement No. 1, American Society of Civil Engineers/Structural  
39 Engineering Institute.
- 40                   **1.3.10**         ASTM A 123/A-02, Standard Specification for Zinc (Hot-Dip  
41 Galvanized) Coating on Iron and Steel Products, ASTM International.
- 42                   **1.3.11**         ASTM C 31-98, Standard Practice for Making and Curing  
43 Concrete Test Specimens in the Field, ASTM International
- 44                   **1.3.12**         ASTM C 33-03, Standard Specification for Concrete  
45 Aggregates, ASTM International

46                    **1.3.13**            ASTM C 39-05e1, Standard Test Method for Compressive  
47                    Strength of Cylindrical Concrete Specimens, ASTM International.

48                    **1.3.14**            ASTM C 387-06a, Standard Specification for Packaged, Dry,  
49                    Combined Materials for Mortar and Concrete; ASTM International.

50                    **1.3.15**            ASTM D 1761-88(2000)e1, Standard Test Methods for  
51                    Mechanical Fasteners in Wood, ASTM International.

52                    **1.3.16**            ASTM D 2395-06, Standard Test Methods for Specific Gravity  
53                    of Wood and Wood-Based Materials, ASTM International.

54                    **1.3.17**            ASTM D 4442-07, Standard Test Methods for Direct Moisture  
55                    Content Measurement of Wood and Wood-Base Materials, ASTM International.

56                    **1.3.18**            ASTM D 7147-05, Standard Specification for Testing and  
57                    Establishing Allowable Loads of Joist Hangers, ASTM International.

58                    **1.3.19**            ASTM F 1470-02, Standard Guide for Fastener Sampling for  
59                    Specified Mechanical Properties and Performance Inspection, ASTM International.

60                    **1.3.20**            ASTM F 1575-03, Standard Test Method for Determining  
61                    Bending Yield Moment of Nails, ASTM International.

62                    **1.3.21**            ASTM F 1667-03, Standard Specification for Driven Fasteners:  
63                    Nails, Spikes and Staples; ASTM International.

64                    **1.4    Definitions:**

65                    **1.4.1    Brittle Steel:** Cold-formed steel with a tensile test elongation of less  
66                    than 14 percent, or a reduction in area of less than 30 percent, or both.

67                    **1.4.2    Cold-formed Steel Connectors:** For purposes of this acceptance  
68                    criteria, a cold-formed steel connector consists of one or more pieces of cold-formed steel

69 having one end embedded in concrete construction and the other end attached to light-  
70 frame construction:

71 **1.4.2.1 Strap Style Hold-down Connector:** A strap style  
72 hold-down connector is prefabricated from cold-formed steel having a portion that embeds  
73 into a concrete foundation before placing concrete and a strap portion that extends above  
74 the concrete and is fastened to a vertical light-frame member(s) with either nails, screws  
75 or bolts. This connector is used to transfer vertical tension forces from the attached light-  
76 frame member(s) to a concrete foundation. Refer to Figure 1 for an example.

77 **1.4.2.2 Structural Concrete Wall Connector:** A structural  
78 concrete wall connector is used as diaphragm-to-wall anchorage in accordance with  
79 Section 12.11.2.2.5 of ASCE 7. The connector is a strap of cold-formed steel having one  
80 end that embeds into the concrete wall before placing concrete and hooks around the wall  
81 reinforcement or otherwise terminates so as to effectively transfer forces to the reinforcing  
82 steel, and the other end that fastens to the sub-diaphragm purlin member. Refer to Figure  
83 2 for an example.

84 **1.4.2.3 Column Base Connector:** A column base connector  
85 is prefabricated from one or more pieces of cold-formed steel having one end that embeds  
86 into a concrete foundation before placing concrete; and a bottom steel plate or standoff  
87 base, which may elevate the supported wood post a specified distance above the concrete;  
88 and the other end that extends above the concrete and is fastened to a vertical light-frame  
89 member(s) with either nails, screws or bolts. This connector is primarily used to resist  
90 vertical tension and compression forces. When used to support wood posts, it may be used  
91 to resist lateral and net induced uplift forces at the bottom of the post in accordance with

92 Section 2304.9.7 of the IBC, and to prevent lateral displacement at the bottom of the post  
93 in accordance with Section R407.3 of the IRC. Refer to Figure 3 for an example.

94 **1.4.2.4 Sill Plate or Bottom Track Foundation Strap**

95 **Connector:** A sill plate or bottom track foundation strap connector is prefabricated from  
96 one piece of cold-formed steel into a device having one end that embeds into a concrete  
97 foundation before placing concrete and the other end that extends above the concrete  
98 member and fastens to a wood sill plate (as permitted by Section 1805.6 of the IBC and  
99 the first exception to Section R403.1.6 of the IRC) with either nails or wood screws or a  
100 cold-formed steel bottom track with self-drilling tapping screws. This connector is used to  
101 resist vertical tension, or uplift, forces and shear forces parallel and perpendicular to the  
102 bottom track. Refer to Figure 4 for an example.

103 **1.4.3 Connector Breakout Failure:** The strength corresponding to a  
104 volume of concrete surrounding the embedded portion of the cold-formed steel connector  
105 and separating from the member. Concrete breakout failure includes concrete cone  
106 breakout under tension load and edge breakout from tension or shear load.

107 **1.4.4 Connector Pullout Failure:** A failure mode in which the portion of the  
108 cast-in-place cold-formed steel connector that pulls out of the concrete without  
109 development of the full steel strength or concrete capacity. Pullout failure occurs when the  
110 connector does not sufficiently engage the concrete to produce a full concrete cone  
111 (breakout) failure. While a concrete cone may occur as part of the pullout failure, it will be  
112 at a shallower embedment depth than for a full concrete cone failure.

113 **1.4.5 Connector Steel Failure:** A failure mode in which the cold-formed  
114 steel connector yields, fractures, buckles, cripples, or ruptures (as defined in AISI-NAS).

115                   **1.4.6 Ductile Steel:** Cold-formed steel with a tensile test elongation of at  
116 least 14 percent and a reduction in area of at least 30 percent.

117                   **1.4.7 Light-frame Construction:** Light-frame construction is a method of  
118 construction where the structural assemblies (e.g., walls, floors, ceilings, and roofs) are  
119 primarily formed by a system of repetitive wood or cold-formed steel framing members or  
120 subassemblies of these members (e.g., trusses).

## 121 **2.0 BASIC INFORMATION**

122                   **2.1 General:** The following information shall be submitted:

123                   **2.1.1 Product Description:** Complete information pertaining to the  
124 connector, including material specifications, drawn-to-scale production drawings showing  
125 all dimensions and tolerances, description of the manufacturing process (including welds  
126 when applicable). Materials shall comply with recognized standards.

127                   **2.1.2 Installation Instructions:** Installation details and drawings, noting  
128 installation requirements and/or limitations.

129                   **2.1.3 Packaging and Identification:** A description of field identification of  
130 the connector. Each connector shall bear an imprint that clearly identifies the manufacturer  
131 (a registered trademark may serve as such identity). Labeling shall also include the model  
132 number and the ICC-ES evaluation report number.

133                   **2.2 Testing Laboratories:** Testing laboratories shall comply with Section 2.0 of  
134 the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the ICC-ES  
135 Rules of Procedure for Evaluation Reports.

136                   **2.3 Test Reports:** Test reports shall comply with AC85 and include the following  
137 information:

138                   **2.3.1** Identification of the test standard used and the date of issue of the  
139 standard, and other relevant information concerning the test procedure, justification for any  
140 deviations from the referenced test standard, and any critical information relevant to the  
141 specific test.

142                   **2.3.2** A description of the sample size of randomly selected cold-formed  
143 steel connectors for each test protocol required by Section 4.1.

144                   **2.3.3** Production drawings of the tested cold-formed steel connector(s),  
145 providing connector dimensions and identifying connector steel specification(s).

146                   **2.3.4** A description of the fasteners including the finish, head configuration,  
147 head diameter, and markings; the measured length and diameter; and strength properties  
148 required in Section 3.1.4.

149                   **2.3.5** Specified and measured steel physical properties of the connector,  
150 including yield point and tensile strength, and (uncoated) base-metal thickness. The test  
151 report shall include the information described in Section 3.1.2 and the necessary data to  
152 derive the steel strength reduction factor,  $R_s$ , in accordance with Section 3.2.1.

153                   **2.3.6** When tested connectors are fastened to wood members, the test  
154 report shall include the data necessary to derive the wood specific gravity reduction factor,  
155  $R_{sg}$ , in accordance with Section 3.2.2.

156                   **2.3.7** When tested connectors are fastened to steel framing members, the  
157 test report shall include the data necessary to derive the steel strength reduction factor,  $R_s$ ,  
158 in accordance with Section 3.2.1.

159                   **2.3.8** A description of the concrete properties, including measured properties  
160 as required in Section 3.1.3, and the necessary data to derive the concrete strength

161 reduction factor,  $R_c$ , in accordance with Section 3.2.3.

162           **2.3.9** Photographs of the test setup and typical failure modes need to be  
163 included in the test report.

164           **2.3.10**       Location of displacement instrumentation and their point of  
165 reference for connection load testing according to Section 3.3.2, including individual and  
166 average load-versus-deformation curves, as plotted directly, or as reprinted from data  
167 acquisition systems.

168           **2.3.11**       Individual and average maximum test load values; and a  
169 description of the general behavior of tested connectors during load application; and a  
170 description of the nature, type and location of failures of tested connectors.

171           **2.4 Product Sampling:** Sampling shall comply with Section 3.1 of AC85 for  
172 welded cold-formed steel connectors. Sampling shall comply with Section 3.2 of AC85 for  
173 cold-formed steel connectors fabricated without welds.

## 174 **3.0 TEST AND PERFORMANCE REQUIREMENTS**

### 175 **3.1 Test Materials:**

#### 176 **3.1.1 Wood:**

177           **3.1.1.1**       All wood materials shall be sawn lumber of structural  
178 quality with allowable values substantiated by accepted procedures, such as those  
179 referenced in Section 2303 of the IBC.

180           **3.1.1.2**       The specific gravity of the wood members used in  
181 connector assembly testing shall have a tested specific gravity, determined in accordance  
182 with ASTM D 2395, within 10 percent of the code specified value, and shall be reported on  
183 an oven-dry basis in accordance with ASTM D 2395. Specific gravity measurements taken

184 at moisture contents other than oven-dry condition shall be adjusted to the oven-dry  
185 moisture content in accordance with Appendix X1 of ASTM D 2395.

186 **3.1.1.3** Test specimens fabricated and tested with sawn lumber  
187 shall have a moisture content of not less than 11 percent. The moisture content of the  
188 wood members shall be determined in accordance with ASTM D 4442 or ASTM D 4444.

189 **3.1.2 Cold-formed Steel:**

190 **3.1.2.1** The yield point and the tensile strength of the steel used  
191 to fabricate the tested cold-formed steel connector(s) and framing members shall be  
192 determined. Standard yield point and tensile strength tests of the steel from which the cold-  
193 formed steel connector(s) and cold-formed steel test specimens was framing members  
194 were produced shall be conducted in accordance with ASTM E 8. Alternatively, the data  
195 are permitted to be obtained from the mill certification of the steel from which the cold-  
196 formed steel connector(s) and framing members are manufactured.

197 **3.1.2.2** Elongation of the steel used to fabricate the tested cold-  
198 formed steel connectors shall be determined according to AISI TS-3 or an approved test  
199 procedure. The test report shall identify the cold-formed steel connector as brittle (as  
200 defined in Section 1.4.1) or as ductile (as defined in Section 1.4.6).

201 **3.1.2.3** The uncoated base-metal thickness of the steel from  
202 which the tested connector(s) and cold-formed steel framing members are formed shall be  
203 measured or calculated. When the base metal thickness is calculated by converting the  
204 coating weight to a coating thickness and subtracting it from the overall measured  
205 thickness, coating weight tests shall be performed on the steel of the tested cold-formed  
206 steel connector(s) and framing members in accordance with the requirements of ASTM A

207 90, ASTM A 924, or ASTM A 123. The following relationship is permitted to be used to  
208 estimate the coating thickness from the coating weight (mass): 1 oz/ft<sup>2</sup> coating weight = 1.7  
209 mils coating thickness (7.14 g/m<sup>2</sup> coating mass = 1 μm coating thickness).

210 **3.1.3 Normal-Weight Concrete:**

211 **3.1.3.1** All concrete materials shall be of structural quality with  
212 values substantiated by accepted procedures, such as those referenced in Section 1903.1  
213 of the IBC.

214 **3.1.3.2** To obtain desired concrete compressive strengths, the  
215 mix shall follow recommendations for proportioning in the Portland Cement Association's  
216 *Design and Control of Concrete Mixtures, 14th Edition, 2002 (rev. 2008); ACI 211.1,*  
217 *Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete,*  
218 and either Chapter 19 of the IBC or ACI 318. Alternatively, combined materials for  
219 concrete that are pre-packaged in accordance with ASTM C 387 may be used. Concrete  
220 test cylinders must be prepared and tested in accordance with ASTM C 31 and ASTM C  
221 39.

222 **3.1.3.3** Coarse and fine aggregate in concrete must comply with  
223 ASTM C 33. The aggregate description must include the rock and mineral components,  
224 shape, hardness, maximum size, and grading specification.

225 **3.1.3.4** Concrete test cylinders must be cured in accordance with  
226 Section 10 of ASTM C 31 for 28 days with a five-day allowable minus tolerance. Where  
227 high-early strength cement is used, curing shall be seven days minimum with a two-day  
228 allowable minus tolerance. Two tests of two cylinders each must be tested and the average  
229 compressive strength reported during a 24-hour period immediately preceding and

230 following any anchor test series. Two cylinder strength results are averaged and constitute  
231 one test. The two tests are averaged (four cylinders total) establishing the compressive  
232 strength of the testing medium.

233 **3.1.3.5** For tests conducted in high-early strength concrete, the  
234 cylinders must be tested and the average compressive strength noted during a 12-hour  
235 period immediately preceding and following any test series.

236 **3.1.3.6** For tests conducted in concrete aged 90 days or more,  
237 the compressive strength must be the average of three test cylinders aged a minimum of  
238 90 days and tested in accordance with Section 3.1.3.2.

239 **3.1.3.7** For tests conducted in existing concrete elements,  
240 compressive strength must be confirmed by obtaining, preparing and testing drilled cores.  
241 Procedures are contained in ASTM C 42. One sample from each of three cores must be  
242 tested and the average compressive strength reported within 24 hours of anchor testing.

243 **3.1.3.8** Reinforcing steel in concrete test members must be  
244 outside the potential failure region of each test connector unless the connector is intended  
245 to be attached to, or hooked around, the reinforcing steel or otherwise terminated so as to  
246 effectively transfer forces to the reinforcing steel. Reinforcement may be used to stabilize  
247 test members during transportation. The testing laboratory must verify location of  
248 reinforcing.

249 **3.1.4 Fasteners:** Fasteners from the same manufacturer's lot that are used  
250 in connector and connector assembly testing shall be sampled in accordance with ASTM  
251 F 1470.

252 **3.1.4.1** Bolts shall comply with ANSI/ASME Standard B18.2.1.

253 Bolt tensile strength shall be derived using the procedures of ASTM F 606.

254 **3.1.4.2** Nails shall comply with ASTM F 1667. Nail bending yield  
255 strength,  $F_{yb}$ , shall be determined in accordance with ASTM F 1575, or the ICC-ES  
256 Acceptance Criteria for Nails and Spikes (AC116), as applicable.

257 **3.1.4.3** Wood screws shall comply with either ANSI/ASME  
258 Standard B18.6.1 or the ICC-ES Acceptance Criteria for Alternate Dowel-type Threaded  
259 Fasteners (AC233). Bending yield strength of the screws shall be derived using the  
260 procedures of Section 4.4 of AC233. Predrilled holes shall be a field requirement when  
261 wood screws are installed into predrilled holes for testing.

262 **3.2 Adjustments to Test Results:** Properties of test materials may exceed the  
263 specified properties for the materials reported in relevant specifications provided  
264 adjustments to test results addressed in Section 3.3 are made.

265 **3.2.1 Steel Strength Reduction Factor:** The steel strength reduction  
266 factor,  $R_s$ , shall be calculated as follows:

$$R_s = \left( \frac{F_{u(spec)}}{F_{u(test)}} \right) \times \left( \frac{t_{spec}}{t_{test}} \right) \leq 1.0$$

267 where:

268  $R_s$  = Steel strength reduction factor.

269  $F_{u(spec)}$  = Tensile strength of the connector steel from the  
270 manufacturer's specifications in the approved quality  
271 documentation, psi (Pa).

272  $F_{u(test)}$  = Measured tensile strength of the connector steel used in

273 the test specimens, psi (Pa). The measured steel tensile  
274 strength value shall not exceed the specified value by more  
275 than 20 percent.

276  $t_{spec}$  = Specified base-metal thickness of the connector steel, in.  
277 (mm).

278  $t_{test}$  = Measured base-metal thickness of the connector steel, in.  
279 (mm).

280 Additionally, if

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

281 then,

$$\left( \frac{t_{spec}}{t_{test}} \right) \leq 1.0$$

282 **3.2.2 Wood Connection Strength Reduction Factors:** The wood specific  
283 gravity reduction factor,  $R_{sg}$ , shall be determined as follows:

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

284 where:

285  $R_{sg}$  = Wood specific gravity reduction factor.

286  $Z_{spec}$  = Sum of all the lateral fastener resistance values calculated  
287 according to the NDS or other approved document and  
288 based on the following: (1) wood member material

289 specified for the installation; (2) fastener quantity, type, and  
290 size specified for the installation; (3) fastener bending yield  
291 strength,  $F_{yb}$ , values for screws or nails published in the  
292 NDS, or published steel tensile strength of the bolts, as  
293 applicable, used to attach the connector to the wood  
294 member; and (4) specified connector steel tensile strength  
295 and base-metal thickness specified for connector  
296 production in the approved quality documentation.

297  $Z_{test}$  = Sum of all the lateral fastener resistance values calculated  
298 according to the NDS or other approved documents and  
299 based on the following: (1) tested properties of the wood  
300 material; (2) fastener quantity, type, and measured size; (3)  
301 tested fastener bending yield strength,  $F_{yb}$ , value of the  
302 screws or nails, or tested steel tensile strength value of the  
303 bolts, as applicable, used to attach the connector to the  
304 wood member; and (4) tested connector steel tensile  
305 strength and measured base-metal thickness.

306 **3.2.3 Concrete Strength Reduction Factor:** The concrete strength  
307 reduction factor,  $R_c$ , shall be determined as follows:

$$R_c = \sqrt{\frac{f'_{c(spec)}}{f'_{c(test)}}} \leq 1.0$$

308 where:

309  $R_c$  = Concrete compressive strength reduction factor. No  
310 increase of the anchorage allowable tension or shear load,  
311  $T_{ASD}$  or  $V_{ASD}$ , respectively, is permitted if the measured  
312 compressive strength is less than the specified  
313 compressive strength.

314  $f'_{c(spec)}$  = Specified concrete compressive strength, psi (Pa).

315  $f'_{c(test)}$  = Measured concrete compressive strength determined in  
316 accordance with Section 3.1.3, psi (Pa).

317 **3.3 Connector Capacity:** The available strength of cold-formed steel connectors  
318 shall be limited by the available steel strength of the portion of the connector external to  
319 the surface of the concrete, the available connection strength of the portion of the  
320 connector fastened to the light-frame member(s), and the available anchorage strength of  
321 the portion of the connector embedded into concrete and designed as anchorage to  
322 concrete.

### 323 **3.3.1 Steel Strength:**

324 **3.3.1.1** The available steel strength shall be determined for the  
325 critical cross-sectional area of the cold-formed steel connector external to the surface of  
326 the concrete in accordance with AISI-NAS. The allowable tension or shear load, or both,  
327 shall be calculated based on the minimum specified mechanical and physical properties  
328 of the steel. Steel thickness shall not include the coating thickness.

329 **3.3.1.2** For connectors of unusual geometry where the steel  
330 strength cannot be calculated, the allowable tension or shear load, or both, shall be  
331 determined according to Section F1 of AISI-NAS with tests conducted in general



355 the test and analysis provisions of the ICC-ES Acceptance Criteria for Joist Hangers and  
356 Similar Devices (AC13), with the following modifications:

357 (a) A qualification test plan shall be submitted to ICC-ES for each  
358 type of connector prior to commencement of testing.

359 (b) The allowable test load determined in accordance with AC13  
360 shall be multiplied by the wood connection strength reduction factor,  $R_{sg}$ , defined in Section  
361 3.2.2, to account for increased fastener perpendicular-to-grain strength used in the tests.

362 **3.3.2.2** Where the light-frame member(s) is cold-formed steel,  
363 the available strength of the connector fastened to the steel member shall be determined  
364 in accordance with applicable provisions of AISI-NAS or the ICC-ES Acceptance Criteria  
365 for Connectors Used with Cold-formed Steel Structural Members (AC261), as applicable.

366 **3.3.2.3** Strap style hold-down connectors and sill plate or bottom  
367 track foundation strap connectors shall be tested to determine the serviceability limit state  
368 for the connector, which shall be the deflection associated with the allowable load  
369 determined for the connector based on the test and analysis provisions of Section 3.3.2.1  
370 or 3.3.2.2, as applicable, but no greater than the average load at which the deflection of  
371 the connector parallel to the application of the test load reaches a serviceability limit state  
372 of  $\frac{1}{8}$  inch (3.2 mm), unless a different serviceability limit state associated with static  
373 deflection can be justified for the connector.

374 **3.3.3 Anchorage Strength:**

375 **3.3.3.1** For cold-formed steel connectors (as defined in Section  
376 1.4.2) designed using Allowable Stress Design (ASD) load combinations in accordance  
377 with IBC Section 1605.3, the allowable anchorage tension strength,  $T_{ASD}$ , and the allowable

378 anchorage shear strength,  $V_{ASD}$ , shall be determined using the following equations:

$$T_{ASD} = \frac{\phi \times N_u \times (1 - K \times COV) \times R_c \times R_d \times R_s \times R_{cr}}{\alpha}$$

$$V_{ASD} = \frac{\phi \times V_u \times (1 - K \times COV) \times R_c \times R_d \times R_s \times R_{cr}}{\alpha}$$

379 where:

380  $T_{ASD}$  = Allowable tension anchorage strength (lbf or kN)

381  $V_{ASD}$  = Allowable shear anchorage strength (lbf or kN)

382  $N_u$  = Average maximum tension test load (minimum of 5 test  
383 specimens) determined in accordance with Section 4.1.

384  $V_u$  = Average maximum shear test load (minimum of 5 test  
385 specimens) determined in accordance with Section 4.1.

386  $COV$  = Coefficient of variation of test results.

387  $K$  = Statistical constant (one-sided tolerance factor) used to  
388 establish the 5 percent fractile with 90 percent confidence,  
389 whose value depends on the number of tests. When 5  
390 tests are performed,  $K$  equals 3.4. See ACI 355.2 Table  
391 A2.1 for  $K$  values to be used when the number of tests is  
392 greater than 5 tests.

393  $R_c$  = Concrete strength reduction factor.  $R_c = 1.0$ , except when  
394 the measured concrete compressive strength (see Section

395 3.1.3) exceeds the specified concrete compressive strength  
396 by more than 10 percent,  $R_c$  shall equal the value  
397 determined in accordance with Section 3.2.3.

398  $R_{cr}$  = Cracked concrete strength reduction factor.  $R_{cr} = 1.0$  when  
399 an analysis indicates no cracking in the concrete at the  
400 location of the connector at service loads, otherwise  $R_{cr} =$   
401 0.70. Alternatively,  $R_{cr}$  shall be permitted to be increased  
402 above 0.70 based on tests in accordance with Section 4.2.

403  $R_d$  = Ductility reduction factor.  $R_d = 1.0$  when the connector  
404 resists forces other than seismic, otherwise  $R_d = 0.75$ .

405  $R_s$  = Steel strength reduction factor, determined in accordance  
406 with Section 3.2.1.

407  $\alpha$  = Conversion factor calculated as a weighted average of the  
408 load factors for the controlling load combination.  $\alpha = 1.0$  to  
409 determine LRFD anchorage strength loads.

410  $\phi$  = Strength reduction factor, which shall be as follows:

411 (a) Connector governed by strength of ductile steel:

412 (i) Tension loads,  $\phi = 0.75$

413 (ii) Shear loads,  $\phi = 0.65$

414 (b) Connector governed by strength of brittle steel:

415 (i) Tension loads,  $\phi = 0.65$

416 (ii) Shear loads,  $\phi = 0.60$

417 (c) Connector governed by concrete:

- 418 (i) Tension loads (breakout failure),  $\phi = 0.75$  when  
419 supplementary reinforcement provided, otherwise  
420  $\phi = 0.70$
- 421 (ii) Tension loads (pullout failure),  $\phi = 0.70$
- 422 (iii) Shear loads,  $\phi = 0.75$  when supplementary  
423 reinforcement provided, otherwise  $\phi = 0.70$

424 **3.3.3.2** Elongation shall be determined according to a  
425 recognized standard. If the elongation is at least 14 percent and the reduction in area is  
426 at least 30 percent, the connector shall be considered to meet the ductile steel  
427 requirements. If the ductility and reduction of area can not be determined, the connector  
428 shall be reported as brittle in the evaluation report.

429 **3.3.3.3** When the connector is fabricated from brittle steel and  
430 the connector is used in Seismic Design Categories C, D, E, and F, either the available  
431 connection strength (as determined in accordance with Section 3.2.2) shall undergo ductile  
432 yielding at a load level corresponding to anchor forces no greater than the available  
433 anchorage strength, or the available anchorage strength shall be reduced by one half.

434 **3.3.3.4** Design strength of steel reinforcement may be used  
435 rather than the concrete breakout strength when reinforcement is installed on both sides  
436 of the breakout surface or encloses the cast-in connector and is developed beyond the  
437 breakout surface using a strength reduction factor,  $\phi$ , equal to 0.75 in the design of the  
438 reinforcement.

## 439 **4.0 TEST METHODS**

### 440 **4.1 Qualification Testing of Cold-formed Steel Connectors Cast-in Concrete:**

441                   **4.1.1 Testing Machine:** A testing machine that is capable of operation at  
442 a constant rate of motion of the movable crosshead or a constant rate of loading, and a  
443 force measuring device that is calibrated in accordance with Method ASTM E 4, shall be  
444 used.

445                   **4.1.2 Concrete Specimen:** Compressive strength of concrete specimens  
446 shall be determined in accordance with Section 3.1.3. Concrete specimens shall be  
447 formed to be representative of end use applications for cold-formed steel connectors.

448                   **4.1.3 Test Sample Size:** Differences in connector size, configuration, and  
449 material specifications shall be the basis for establishing a test sample size. A minimum  
450 of five connectors for each type of device (size, configuration, and material specifications)  
451 shall be tested for each load direction sought for recognition. Test connectors shall be  
452 tested at the minimum and maximum embedment for which recognition is desired.

453                   **4.1.4 Test Setup:** Connectors shall be tested individually in such a manner  
454 to simulate the essential function of the connector as anchorage to concrete. Connectors  
455 shall be attached to a steel jig to try to preclude steel connection failures. The test setup  
456 shall be configured to ensure a concrete breakout failure (Section 1.4.3) or a concrete  
457 pullout failure (Section 1.4.4). Test loads shall be applied with reference to the intended  
458 end-use application of the connector. Low-friction rollers are permitted to be used in the  
459 test setup to prevent lateral movement of the steel jig due to eccentricity.

460                   **4.1.5 Test Procedure:** An initial load, or preload, shall not be applied for  
461 tension (uplift) load or shear (required for sill plate and bottom track anchorage) testing of  
462 connectors. The prohibition on applying a preload is based upon the premise that these  
463 connectors are designed and installed to resist short-term loading, such as wind or seismic

464 loads, where no settling of the installed connector, induced by the wind or seismic forces,  
465 occurs in the loading direction prior to the application of the wind or seismic design loads.  
466 Cold-formed steel anchors embedded at locations representative of end use installations  
467 in concrete test specimens shall be tested in general agreement with ASTM E 488. When  
468 it is necessary to deviate from the ASTM E 488 test method, the test report shall include  
469 a clear description of the deviations and the reason for their implementation.

470 **4.2 Connector Testing to Determine Cracked Concrete Reduction Factor:**

471 **4.2.1** These tests are in addition to structural load tests of the connector in  
472 the actual installed condition to determine the anchorage strength in accordance with  
473 Section 3.3.3. A minimum of 5 tests in the cracked specimen and 5 in the uncracked  
474 specimen shall be performed. It is permitted to test the connector in the same product  
475 series with shortest embedded portion and the deepest embedded portion to determine the  
476 reduction factor(s).

477 **4.2.2** The width and length of the concrete test specimen shall be such so  
478 that there is a minimum of 2 times the vertical dimension of the embedded portion ( $l_e$ ) of  
479 the connector on either side along the length of the concrete test specimen measured from  
480 the centerline of the connector to each edge. The thickness of the test specimen shall be  
481 such so as the same failure mode occurs as in the installation conditions of the tests  
482 conducted in accordance with Section 4.1. The support members shall be no closer than  
483  $2l_e$  from the centerline of the connector.

484 **4.2.3** The depth of the concrete test specimen shall be a minimum of 1.5  
485 times the vertical dimension of the connector embedded in the concrete.

486 **4.2.4** A concrete test specimen shall have a minimum 0.012 inch (0.30 mm)

487 wide crack induced along the entire depth of the test specimen centered on the connector.

488 Refer to Figure 5.

489 **4.2.5** If a shear test is performed on the connector, the load shall be applied  
490 perpendicular to the induced crack. Refer to Figure 6.

491 **4.2.6** The cracked concrete reduction factor shall be determined by dividing  
492 the connector average peak load from the cracked concrete specimen tests by the  
493 connector average peak load from the uncracked concrete specimen tests. This factor  
494 may be considered to be 1.0 if the difference is less than 10 percent.

## 495 **5.0 QUALITY CONTROL**

496 **5.1** Welded connectors shall be manufactured under an approved quality control  
497 program with inspections by an inspection agency accredited by the International  
498 Accreditation Service (IAS) or otherwise acceptable to ICC-ES. Third-party follow-up  
499 inspections are not required under this acceptance criteria for non-welded connectors.

500 **5.2** Quality documentation complying with the ICC-ES Acceptance Criteria for  
501 Quality Documentation (AC10) shall be submitted.

## 502 **6.0 EVALUATION REPORT RECOGNITION**

503 **6.1** The evaluation report shall describe the connector with respect to material  
504 specifications.

505 **6.2** The evaluation report shall provide a table or table footnotes specifying the  
506 following information:

507 **6.2.1** Connector dimensions.

508 **6.2.2** Required fasteners, including type, number, and size, for attaching the  
509 connector to the wood or cold-formed steel member. Additionally, a note indicating whether

510 predrilled holes are required.

511           **6.2.3** Required minimum specified concrete compressive strength.

512           **6.2.4** Edge, end and spacing dimension requirements for cast-in connector.

513           **6.2.5** Reinforcement requirements (if used above the embedded portion of  
514 the connector in the test program).

515           **6.3** The evaluation report shall include the following statements for connectors  
516 used for wood construction:

517           **6.3.1** The allowable loads shown in the product tables of this report are  
518 based on allowable stress design and include the load duration factor,  $C_D$ , corresponding  
519 with the applicable loads in accordance with the NDS.

520           **6.3.2** Tabulated allowable loads apply to products connected to wood used  
521 under dry conditions and where sustained temperatures are 100°F (37.8°C) or less. When  
522 products are installed to wood having a moisture content greater than 19 percent (16  
523 percent for engineered wood products), or where wet service is expected, allowable loads  
524 must be adjusted by the wet service factor,  $C_M$ , as specified in the NDS. When connectors  
525 are installed in wood that will experience sustained exposure to temperatures exceeding  
526 100°F (37.8°C), the allowable loads in this report must be adjusted by the temperature  
527 factor,  $C_t$ , specified in the NDS.

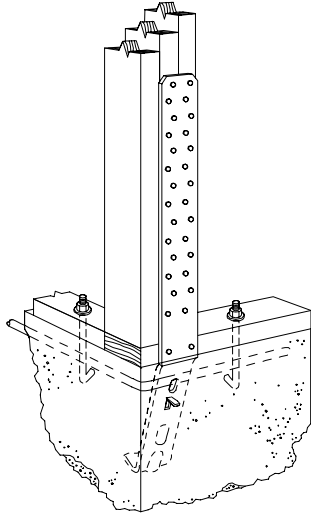
528           **6.4** The evaluation report shall include the following statement concerning  
529 installation: "Installation of the connectors must be in accordance with this evaluation report  
530 and the manufacturer's published installation instructions. In the event of a conflict between  
531 this report and the manufacturer's published installation instructions, this report governs."

532           **6.5** The evaluation report shall include the following statements when the cast-in

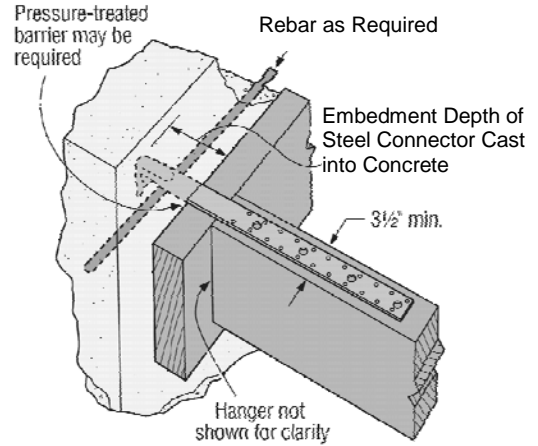
533 connectors are used as a component in the seismic force resisting system:

534                   **6.5.1** For jurisdictions adopting the IBC, periodic special inspection shall be  
535 provided for components within the seismic-force-resisting system in Seismic Design  
536 Categories C, D, E or F in accordance with Section 1707.3 or 1707.4, with the exception  
537 of those structures that qualify under Section 1704.1.

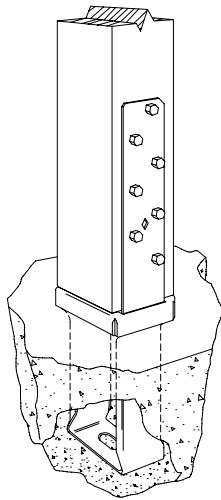
538                   **6.5.2** For jurisdictions adopting the IRC, special inspections shall not be  
539 required. ■



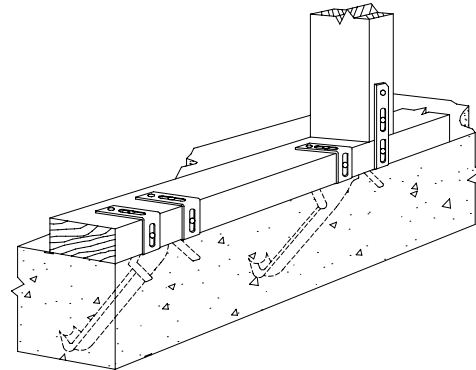
**FIGURE 1—EXAMPLE OF A STRAP STYLE  
HOLD-DOWN CONNECTOR AS DEFINED IN  
SECTION 1.4.2.1**



**FIGURE 2—EXAMPLE OF A STRUCTURAL  
CONCRETE WALL CONNECTOR AS DEFINED IN  
SECTION 1.4.2.2**



**FIGURE 3—EXAMPLE OF A COLUMN  
BASE CONNECTOR AS DEFINED IN  
SECTION 1.4.2.3**



**FIGURE 4—EXAMPLE OF A SILL PLATE  
OR BOTTOM TRACK FOUNDATION  
STRAP CONNECTOR AS DEFINED IN  
SECTION 1.4.2.3**

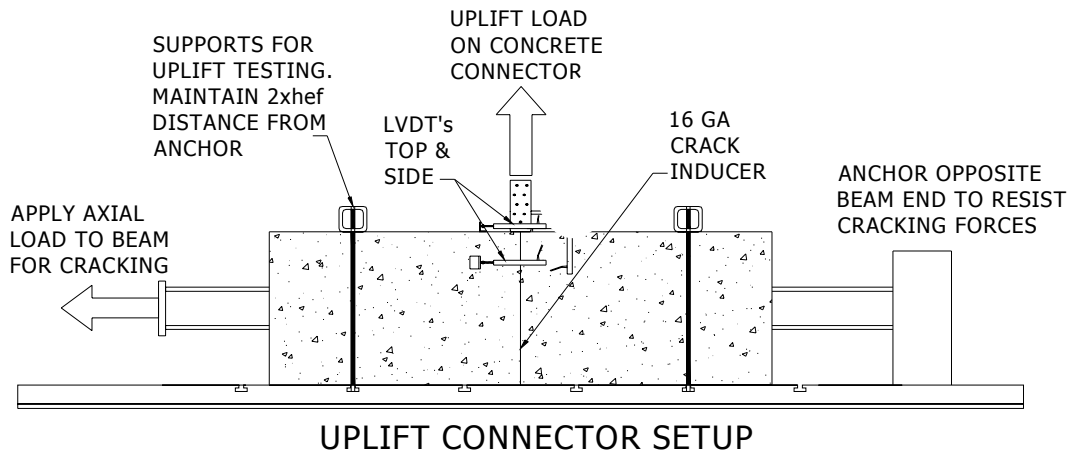


FIGURE 5—ELEVATION OF CRACKED CONCRETE TEST SPECIMEN FOR TENSION TESTING OF A STRAP STYLE HOLD-DOWN CONNECTOR

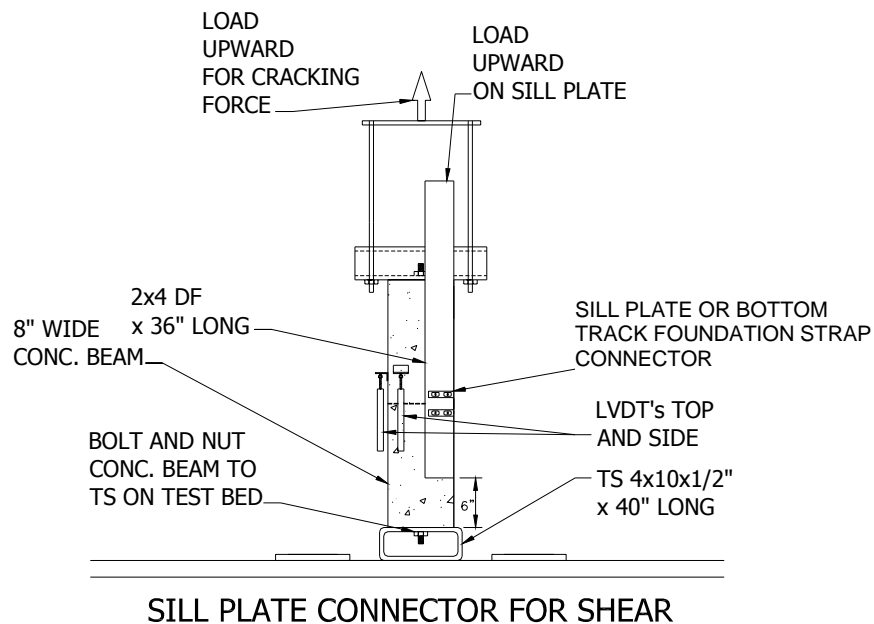


FIGURE 6—ELEVATION OF CRACKED CONCRETE TEST SPECIMEN FOR SHEAR TESTING OF A SILL PLATE OR BOTTOM TRACK FOUNDATION STRAP CONNECTOR