



August 15, 2008

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

SUBJECT: Proposed Acceptance Criteria for Cast-in-place Cold-formed Sheet Steel Connectors in Concrete for Light-frame Construction, Subject AC398-0808-R3 (PB)

Dear Madam or Sir:

The subject acceptance criteria was discussed at the May 30, 2008, Evaluation Committee hearing. Subsequent to that, it was revised and posted on the ICC-ES alternate process for acceptance criteria to allow for public comment. The following correspondence were received and considered by staff in re-drafting the subject acceptance criteria that is attached to this letter:

1. Letter prepared by John Silva, P.E., S.E.; Director, Codes and Standards; Hilti North America; with 8-page tabulated attachment; dated June 26, 2008.
2. Memo prepared by Jake Olsen, P.E., Powers Fasteners, not dated.
3. Memo prepared by Mark Ziegler, P.E., Powers Fasteners, not dated.
4. Letter prepared by David S. Gromala, P.E., Director of Codes and Product Acceptance; iLevel Division, Weyerhaeuser; dated July 2, 2008.
5. Letter prepared by Jeff Ellis, P.E., S.E., Senior Engineering Project Manager; Simpson Strong-Tie Company, Inc.; dated July 3, 2008.
6. Letter prepared by Greg Greenlee, P.E., Director of Engineering; USP, a Gibraltar Industries Company; dated July 3, 2008.
7. Memorandum prepared by Reynaud Serrette; Center for Light Frame Structural Research, Department of Civil Engineering, Santa Clara University; dated June 30, 2008.
8. Letter prepared by Ray Yu, P.E., S.E., Vice President of Engineering; Hardy Frames Inc., a Mitek Company; dated June 13, 2008.

You are cordially invited to submit written comments, within 30 days of the date of this letter. Please use the comment form on the web site attaching any letters to the form. 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.

All comments received in the 30-day comment period will be considered. During this same 30-day period, however, the draft criteria will be balloted to the Evaluation Committee. If the public comments raise major issues, generate controversy, or require the criteria to be substantially rewritten, then ICC-ES staff may decide to reballot the criteria; or place a revised draft on the web site for further public comment; or put the criteria on the agenda for a future Evaluation Committee meeting.

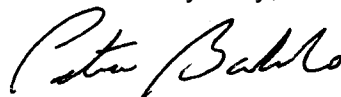
Correspondence received and a memo outlining staff's resolution of the comments in the correspondence will be posted on the web site shortly after the close of the comment period.

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.

Please submit all comments using the form on the web site. Attach any letters to the comment form. If you have any questions (not comments), please contact the undersigned at (800) 423-6587, extension 3306. You may also reach us by e-mail at es@icc-es.org.

Yours very truly,



Peter Bahlo
Senior Staff Engineer

PB/raf

Enclosure

cc: Evaluation Committee



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

AC398

Proposed August 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*[®] 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
SHEET STEEL CONNECTORS IN CONCRETE FOR LIGHT-FRAME
CONSTRUCTION (AC398)**

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 sheet steel
4 connectors in concrete for light-frame construction under Sections 104.11, 1911, 1912,
5 and 2303.5 of the 2006 *International Building Code*[®] (IBC), and Section R104.11 of the
6 2006 *International Residential Code*[®] (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 sheet steel connectors used as anchorage to concrete for light-frame
10 construction.

11 **1.2 Scope:**

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

16 **1.2.2** The provisions of this criteria shall be used to establish the
17 allowable strength and the design strength of cold-formed sheet steel connectors based
18 on Allowable Stress Design (ASD) and Load and Resistance Factored Design (LRFD)
19 methods, respectively, where connector available strength is derived considering
20 measured (tested) and calculated strength characteristics, and measured (tested)
21 displacements.

22 **1.2.3** The provisions of this criteria shall be applicable only to the

23 cold-formed steel connectors as defined in Section 1.4.3 of this criteria.

24 **1.3 Codes and Referenced Standards:**

25 **1.3.1** 2006 *International Building Code*[®], International Code Council.

26 **1.3.2** 2006 *International Residential Code*[®], International Code Council.

27 **1.3.3** ACI 355.2-04, Qualification of Post-Installed Mechanical Anchors in
28 Concrete and Commentary, American Concrete Institute.

29 **1.3.4** AISI (2001), North American Specification for the Design of
30 Cold-formed Steel Structural Members (AISI-NAS) with Appendix A, including 2004
31 Supplement; American Iron and Steel Institute.

32 **1.3.5** AISI General-04, Standard for Cold-Formed Steel
33 Framing—General Provisions, American Iron and Steel Institute.

34 **1.3.6** AISI TS-3-02, Standard Methods for Determination of Uniform and
35 Local Ductility, American Iron and Steel Institute.

36 **1.3.7** AISI TS-5-02, Test Methods for Mechanically Fastened Cold-
37 Formed Steel Connections, American Iron and Steel Institute.

38 **1.3.8** ANSI/AF&PA (2005) National Design Specification for Wood
39 Construction (NDS) and Supplement, American Forest & Paper Association.

40 **1.3.9** ANSI/ASME Standard B18.2.1-1996, Square and Hex Bolts and
41 Screws, Inch Series; American Society of Mechanical Engineers.

42 **1.3.10** ASCE/SEI 7-05, Minimum Design Loads for Buildings and
43 Other Structures including Supplement No. 1, American Society of Civil
44 Engineers/Structural Engineering Institute.

45 **1.3.11** ASTM A 123/A-02, Standard Specification for Zinc (Hot-Dip
46 Galvanized) Coating on Iron and Steel Products, ASTM International.

- 47 **1.3.12** ASTM C 31-98, Standard Practice for Making and Curing
48 Concrete Test Specimens in the Field, ASTM International
- 49 **1.3.13** ASTM C 33-03, Standard Specification for Concrete
50 Aggregates, ASTM International
- 51 **1.3.14** ASTM C 39-05e1, Standard Test Method for Compressive
52 Strength of Cylindrical Concrete Specimens, ASTM International.
- 53 **1.3.15** ASTM C 387-06a, Standard Specification for Packaged, Dry,
54 Combined Materials for Mortar and Concrete; ASTM International.
- 55 **1.3.16** ASTM C 1513-01, Standard for Steel Tapping Screws for
56 Cold-Formed Steel Framing Connections; ASTM International
- 57 **1.3.17** ASTM D 1761-88(2000)e1, Standard Test Methods for
58 Mechanical Fasteners in Wood, ASTM International.
- 59 **1.3.18** ASTM D 2395-06, Standard Test Methods for Specific
60 Gravity of Wood and Wood-Based Materials, ASTM International.
- 61 **1.3.19** ASTM D 4442-07, Standard Test Methods for Direct
62 Moisture Content Measurement of Wood and Wood-Base Materials, ASTM
63 International.
- 64 **1.3.20** ASTM D 7147-05, Standard Specification for Testing and
65 Establishing Allowable Loads of Joist Hangers, ASTM International.
- 66 **1.3.21** ASTM F 1470-02, Standard Guide for Fastener Sampling for
67 Specified Mechanical Properties and Performance Inspection, ASTM International.
- 68 **1.3.22** ASTM F 1575-03, Standard Test Method for Determining
69 Bending Yield Moment of Nails, ASTM International.
- 70 **1.3.23** ASTM F 1667-03, Standard Specification for Driven

71 Fasteners: Nails, Spikes and Staples; ASTM International.

72 **1.4 Definitions:**

73 **1.4.1 Available Anchorage Strength:** Either the allowable strength
74 (ASD) or the design strength (LRFD) of the portion of the cold-formed sheet steel
75 connector cast into the concrete and used to transmit applied loads.

76 **1.4.2 Brittle Steel:** Cold-formed sheet steel with a tensile test elongation
77 of less than 14 percent, or a reduction in area of less than 30 percent, or both.

78 **1.4.3 Cold-formed Sheet Steel Connectors:** For purposes of this
79 acceptance criteria, a cold-formed sheet steel connector consists of one or more pieces
80 of cold-formed steel having one end embedded in concrete construction and the other
81 end attached to light-frame construction. Only connector types noted in the definitions
82 below may be evaluated using this criteria, except for alternate connector types
83 deemed by ICC-ES to be relevant to the scope of this document:

84 **1.4.3.1 Strap Style Hold-down Connector:** A strap style
85 hold-down connector is prefabricated from cold-formed sheet steel having a portion that
86 embeds into a concrete foundation before placing concrete and a strap portion that
87 extends above the concrete and is fastened to a vertical light-frame member(s) with
88 either nails, screws or bolts. This connector is used to transfer vertical tension forces
89 from the attached light-frame member(s) to a concrete foundation. Refer to Figure 1 for
90 an example.

91 **1.4.3.2 Structural Concrete Wall Connector:** A structural
92 concrete wall connector is used as horizontal diaphragm-to-wall anchorage in
93 accordance with Section 12.11.2.2.5 of ASCE 7. The connector is a strap of cold-
94 formed sheet steel having one end that embeds into the concrete wall before placing

95 concrete. In seismic design categories C, D, E, and F, the embedded end shall hook
96 around the wall reinforcement or otherwise terminate so as to effectively transfer forces
97 to the reinforcing steel, and the other end shall be fastened to the diaphragm framing
98 member. Refer to Figure 2 for an example.

99 **1.4.3.3 Column Base Connector:** A column base connector
100 is prefabricated from one or more pieces of cold-formed steel having one end that
101 embeds into a concrete foundation before placing concrete; and a bottom steel plate or
102 standoff base, which may elevate the supported wood post a specified distance above
103 the concrete; and the other end that extends above the concrete and is fastened to a
104 vertical light-frame member(s) with either nails, screws or bolts. This connector is
105 primarily used to resist vertical tension and compression forces. When used to support
106 wood posts, it may be used to resist lateral and net induced uplift forces at the bottom
107 of the post in accordance with Section 2304.9.7 of the IBC, and to prevent lateral
108 displacement at the bottom of the post in accordance with Section R407.3 of the IRC.
109 Refer to Figure 3 for an example.

110 **1.4.3.4 Foundation Anchor Strap:** A foundation anchor
111 strap is prefabricated from cold-formed sheet steel and has one end that embeds into a
112 concrete foundation before placing concrete and the other end that extends above the
113 concrete member and fastens to a wood sill plate (as permitted by Section 1805.6 of
114 the IBC and the first exception to Section R403.1.6 of the IRC) with either nails or wood
115 screws or a cold-formed sheet steel bottom track with self-drilling tapping screws. This
116 connector is used to resist vertical tension (uplift) forces and shear forces parallel and
117 perpendicular to the bottom plate or track. Refer to Figure 4 for an example.

118 **1.4.4 Cold-formed Steel Framing:** Cold-formed steel framing members

119 are structural members designed or intended to support load and are fabricated with
120 steel in accordance with AISI-NAS Section A2. AISI-General Provisions shall apply to
121 the design, construction and installation of cold-formed steel framing members.

122 **1.4.5 Connector Breakout Failure:** The strength corresponding to a
123 volume of concrete surrounding the embedded portion of the cold-formed sheet steel
124 connector and separating from the concrete member. Concrete breakout failure
125 includes concrete cone breakout under tension load and edge breakout from tension or
126 shear load.

127 **1.4.6 Connector Pullout Failure:** A failure mode in which the embedded
128 portion of the cold-formed sheet steel connector, or a major component of the
129 embedded portion of the connector, pulls out from the concrete without breaking out a
130 substantial portion of the surrounding concrete.

131 **1.4.7 Connector Steel Failure:** A failure mode in which the cold-formed
132 sheet steel connector yields, fractures, buckles, cripples, or ruptures.

133 **1.4.8 Ductile Steel:** Cold-formed sheet steel with a tensile test
134 elongation of at least 14 percent and a reduction in area of at least 30 percent.

135 **1.4.9 Light-frame Construction:** Light-frame construction is a method
136 of construction where the structural assemblies (e.g., walls, floors, ceilings, and roofs)
137 are primarily formed by a system of repetitive wood or cold-formed steel framing
138 members or subassemblies of these members (e.g., trusses).

139 **2.0 BASIC INFORMATION**

140 **2.1 General:** The following information shall be submitted:

141 **2.1.1 Product Description:** Complete information pertaining to the
142 connector, including material specifications, drawn-to-scale production drawings

143 showing all dimensions and tolerances, description of the manufacturing process
144 (including welds when applicable). Materials shall comply with recognized standards.

145 **2.1.2 Installation Instructions:** Installation details and drawings, noting
146 installation requirements and/or limitations.

147 **2.1.3 Packaging and Identification:** A description of field identification
148 of the connector. Each connector shall bear an imprint that clearly identifies the
149 manufacturer (a registered trademark may serve as such identity). Labeling shall also
150 include the model number and the ICC-ES evaluation report number.

151 **2.2 Testing Laboratories:** Testing laboratories shall comply with Section 2.0
152 of the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the
153 ICC-ES Rules of Procedure for Evaluation Reports.

154 **2.3 Test Reports:** Test reports shall comply with AC85 and include the
155 following information:

156 **2.3.1** Identification of the test standard used and the date of issue of the
157 standard, and other relevant information concerning the test procedure, justification for
158 any deviations from the referenced test standard, and any critical information relevant
159 to the specific test.

160 **2.3.2** A description of the sample size of randomly selected cold-formed
161 sheet steel connectors for each test protocol required by Section 4.1.

162 **2.3.3** Production drawings of the tested cold-formed sheet steel
163 connector(s), providing connector dimensions and identifying connector steel
164 specification(s).

165 **2.3.4** A description of the fasteners including the finish, head
166 configuration, head diameter, and markings; the measured length and diameter; and

167 strength properties required in Section 3.1.4.

168 **2.3.5** Specified minimum physical properties associated with a particular
169 ASTM standard, and measured steel physical properties of the connector, including
170 yield point and tensile strength, and (uncoated) base-metal thickness. The test report
171 shall include the information described in Section 3.1.2 and the necessary data to
172 derive the steel strength reduction factor, R_s , in accordance with Section 3.2.1.

173 **2.3.6** When tested connectors are fastened to wood members, the test
174 report shall include the data necessary to derive the wood specific gravity reduction
175 factor, R_{sg} , in accordance with Section 3.2.2.

176 **2.3.7** When tested connectors are fastened to steel framing members,
177 the test report shall include the data necessary to derive the steel strength reduction
178 factor, R_s , in accordance with Section 3.2.1.

179 **2.3.8** A description of the concrete properties, including measured
180 properties as required in Section 3.1.3, and the necessary data to derive the concrete
181 strength reduction factor, R_c , in accordance with Section 3.2.3.

182 **2.3.9** Photographs of the test setup and typical failure modes need to be
183 included in the test report.

184 **2.3.10** Location of displacement instrumentation and their point of
185 reference for connection load testing according to Section 3.3.2, including individual
186 and average load-versus-deformation curves, as plotted directly, or as reprinted from
187 data acquisition systems.

188 **2.3.11** Individual and average maximum test load values; and a
189 description of the general behavior of tested connectors during load application; and a
190 description of the nature, type and location of failures of tested connectors.

191 **2.3.12** Description of the test setup and method of how the crack
192 was induced if cracked concrete testing is performed in accordance with Section 4.2.

193 **2.4 Product Sampling:** Sampling shall comply with Section 3.1 of AC85 for
194 welded cold-formed sheet steel connectors. Sampling shall comply with Section 3.2 of
195 AC85 for cold-formed sheet steel connectors fabricated without welds.

196 **3.0 TEST AND PERFORMANCE REQUIREMENTS**

197 **3.1 Test Materials:**

198 **3.1.1 Wood:**

199 **3.1.1.1** All wood materials shall be sawn lumber of structural
200 quality with allowable values substantiated by accepted procedures, such as those
201 referenced in Section 2303 of the IBC.

202 **3.1.1.2** The specific gravity of the wood members used in
203 connector assembly testing shall have a tested specific gravity, determined in
204 accordance with ASTM D 2395, within 10 percent of the code specified value, and shall
205 be reported on an oven-dry basis in accordance with ASTM D 2395. Specific gravity
206 measurements taken at moisture contents other than oven-dry condition shall be
207 adjusted to the oven-dry moisture content in accordance with Appendix X1 of ASTM D
208 2395.

209 **3.1.1.3** Test specimens fabricated and tested with sawn
210 lumber shall have a moisture content of not less than 11 percent. The moisture content
211 of the wood members shall be determined in accordance with ASTM D 4442 or ASTM
212 D 4444.

213 **3.1.2 Cold-formed sheet steel:**

214 **3.1.2.1** The yield point and the tensile strength of the steel

215 used to fabricate the tested cold-formed sheet steel connector(s) and framing members
216 shall be determined. Standard yield point and tensile strength tests of the steel from
217 which the cold-formed sheet steel connector(s) and cold-formed steel test specimens
218 were produced shall be conducted in accordance with ASTM E 8. Alternatively, the
219 data are permitted to be obtained from the mill certification of the steel from which the
220 cold-formed sheet steel connector(s) and framing members are manufactured.

221 **3.1.2.2** Elongation of the steel used to fabricate the tested
222 cold-formed sheet steel connectors shall be determined according to AISI TS-3 or an
223 approved test procedure. The test report shall identify the cold-formed sheet steel
224 connector as brittle (as defined in Section 1.4.2) or as ductile (as defined in Section
225 1.4.7).

226 **3.1.2.3** The uncoated base-metal thickness of the steel from
227 which the tested connector(s) and cold-formed steel framing members are formed shall
228 be measured or calculated. When the base metal thickness is calculated by converting
229 the coating weight to a coating thickness and subtracting it from the overall measured
230 thickness, coating weight tests shall be performed on the steel of the tested cold-
231 formed sheet steel connector(s) and framing members in accordance with the
232 requirements of ASTM A 90, ASTM A 924, or ASTM A 123. The following relationship is
233 permitted to be used to estimate the zinc coating thickness from the zinc coating weight
234 (mass): 1 oz/ft² coating weight = 1.7 mils coating thickness (7.14 g/m² coating mass = 1
235 μm coating thickness).

236 **3.1.3 Normal-Weight Concrete:**

237 **3.1.3.1** All concrete materials shall be of structural quality
238 with values substantiated by accepted procedures, such as those referenced in Section

239 1903.1 of the IBC.

240 **3.1.3.2** To obtain desired concrete compressive strengths,
241 the mix shall follow recommendations for proportioning in the Portland Cement
242 Association's *Design and Control of Concrete Mixtures, 14th Edition, 2002* (rev. 2008);
243 *ACI 211.1, Standard Practice for Selecting Proportions for Normal, Heavyweight, and*
244 *Mass Concrete*, and either Chapter 19 of the IBC or ACI 318. Alternatively, combined
245 materials for concrete that are pre-packaged in accordance with ASTM C 387 may be
246 used. Concrete test cylinders shall be prepared and tested in accordance with ASTM C
247 31 and ASTM C 39.

248 **3.1.3.3** Coarse and fine aggregate in concrete shall comply
249 with ASTM C 33. The aggregate description must include the rock and mineral
250 components, shape, hardness, maximum size, and grading specification.

251 **3.1.3.4** Concrete test cylinders shall be cured in accordance
252 with Section 10 of ASTM C 31 for 28 days with a five-day allowable minus tolerance.
253 Where high-early strength cement is used, curing shall be seven days minimum with a
254 two-day allowable minus tolerance. Two tests of two cylinders each shall be tested and
255 the average compressive strength reported during a 24-hour period immediately
256 preceding and following any connector test series. Two cylinder strength results shall be
257 averaged and constitute one test. The two tests shall be averaged (four cylinders total)
258 establishing the compressive strength of the testing medium.

259 **3.1.3.5** For tests conducted in high-early strength concrete,
260 the cylinders shall be tested and the average compressive strength noted during a 12-
261 hour period immediately preceding and following any test series.

262 **3.1.3.6** For tests conducted in concrete aged 90 days or
263 more, the compressive strength shall be the average of three test cylinders aged a
264 minimum of 90 days and tested in accordance with Section 3.1.3.2.

265 **3.1.3.7** Reinforcing steel in concrete test members shall be
266 outside the potential failure region of each test connector unless the connector is
267 intended to be attached to, or hooked around, the reinforcing steel or otherwise
268 terminated so as to effectively transfer forces to the reinforcing steel. Reinforcement
269 may be used to stabilize test members during transportation. The testing laboratory
270 shall verify location of reinforcing.

271 **3.1.4 Fasteners:** Fasteners from the same manufacturer's lot that are
272 used in connector testing shall be sampled in accordance with ASTM F 1470.

273 **3.1.4.1** Bolts shall comply with ANSI/ASME Standard
274 B18.2.1. Bolt tensile strength shall be derived using the procedures of ASTM F 606.

275 **3.1.4.2** Nails shall comply with ASTM F 1667. Nail bending
276 yield strength, F_{yb} , shall be determined in accordance with ASTM F 1575, or the ICC-ES
277 Acceptance Criteria for Nails and Spikes (AC116), as applicable.

278 **3.1.4.3** Wood screws shall comply with either ANSI/ASME
279 Standard B18.6.1 or the ICC-ES Acceptance Criteria for Alternate Dowel-type Threaded
280 Fasteners (AC233). Bending yield strength of the screws shall be derived using the
281 procedures of Section 4.4 of AC233. Predrilled holes shall be a field requirement when
282 wood screws are installed into predrilled holes for testing and instructions shall be
283 included in the report as to how to pre-drill the holes.

284 **3.1.4.4** Steel self-piercing or self-drilling tapping screws for
285 cold-formed steel light-frame construction shall comply with either ASTM C 1513 or the

286 ICC-ES Acceptance Criteria for Tapping Screw Fasteners (AC118).

287 **3.2 Adjustments to Test Results:** Properties of test materials may exceed
288 the specified properties for the materials reported in relevant specifications provided
289 adjustments to test results addressed in Section 3.3 are made.

290 **3.2.1 Steel Strength Reduction Factor:** The steel strength reduction
291 factor, R_s , shall be calculated as follows:

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

292 where:

293 R_s = Steel strength reduction factor.

294 $F_{u(spec)}$ = Tensile strength of the connector steel from the
295 manufacturer's specifications in the approved quality
296 documentation, or tensile strength of cold-formed steel
297 framing members, psi (Pa).

298 $F_{u(test)}$ = Measured tensile strength of the connector steel or cold-
299 formed steel framing member used in the test
300 specimens, psi (Pa). The measured steel tensile strength
301 value shall not exceed the specified value by more than
302 20 percent.

303 t_{spec} = Specified (design) base-metal thickness of the connector
304 steel or cold-formed steel framing member, in. (mm).

305 t_{test} = Measured base-metal thickness of the connector steel or
306 cold-formed steel framing member, in. (mm).

307 Additionally, if

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

308 then,

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

309 **3.2.2 Wood Connection Strength Reduction Factor:** The wood
310 specific gravity reduction factor, R_{sg} , shall be determined as follows:

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

311 where:

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

313 Z_{spec} = Sum of all the lateral fastener resistance values

314 calculated according to the NDS or other approved

315 document and based on the following: (1) wood

316 member material specified for the installation; (2)

317 fastener quantity, type, and size specified for the

318 installation; (3) fastener bending yield strength, F_{yb} ,

319 values for screws or nails published in the NDS, or

320 published steel tensile strength of the bolts, as

321 applicable, used to attach the connector to the wood

322 member; and (4) specified connector steel tensile

323 strength and base-metal thickness specified for
324 connector production in the approved quality
325 documentation.
326 Z_{test} = Sum of all the lateral fastener resistance values
327 calculated according to the NDS or other approved
328 documents and based on the following: (1) tested
329 properties of the wood material; (2) fastener quantity,
330 type, and measured size; (3) tested fastener bending
331 yield strength, F_{yb} , value of the screws or nails, or
332 tested steel tensile strength value of the bolts, as
333 applicable, used to attach the connector to the wood
334 member; and (4) tested connector steel tensile
335 strength and measured base-metal thickness.

336 **3.2.3 Concrete Strength Reduction Factor:** The concrete strength
337 reduction factor, R_c , shall be determined as follows:

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

338 where:

339 R_c = Concrete compressive strength reduction factor. No
340 increase of the available tension or shear anchorage
341 strength, T or V , respectively, is permitted if the
342 measured compressive strength is less than the
343 specified compressive strength.

344 $f'_{c(spec)}$ = Specified concrete compressive strength, psi (Pa).

345 $f'_{c (test)}$ = Measured concrete compressive strength determined
346 in accordance with Section 3.1.3, psi (Pa).

347 **3.3 Connector Capacity:** The available strength of cold-formed sheet steel
348 connectors shall be limited by the available steel strength of the portion of the
349 connector external to the surface of the concrete, the available connection strength of
350 the portion of the connector fastened to the light-frame member(s), and the available
351 anchorage strength of the portion of the connector embedded into concrete and
352 designed as anchorage to concrete.

353 **3.3.1 Steel Strength:**

354 **3.3.1.1** The available steel strength shall be determined for
355 the critical cross-sectional area of the cold-formed sheet steel connector external to the
356 surface of the concrete in accordance with AISI-NAS. The allowable tension or shear
357 load, or both, shall be calculated based on the minimum specified mechanical and
358 physical properties of the steel. Steel thickness shall not include the coating thickness.

359 **3.3.1.2** For connectors of unusual geometry where the steel
360 strength cannot be calculated, the allowable (ASD) and design (LRFD) tension or shear
361 strength, or both, shall be determined according to Section F1 of AISI-NAS with tests
362 conducted in general agreement with AISI TS-5. Testing cold-formed sheet steel
363 connectors attached to a wood member rather than a steel jig is acceptable provided
364 fastener strength is adequate to precipitate steel failure of the connectors. A
365 qualification test plan needs to be submitted to ICC-ES for each type of connector prior
366 to commencement of testing.

367 **3.3.1.3** If the tensile strength of the steel from which the
368 tested cold-formed connector exceeds the specified minimum value, the test results

369 shall be calibrated to the specified minimum tensile strength of the steel that the
370 manufacturer intends to use by the steel strength adjustment factor, R_s , defined in
371 Section 3.2.1. The tested steel tensile strength value shall not exceed the specified
372 value by more than 20 percent. A similar adjustment shall be made on the basis of
373 yield point instead of tensile strength where yield point is a critical factor.

374 **3.3.1.4** If the measured thickness of the steel, from which the
375 connector is fabricated, exceeds the specified thickness by more than 5 percent, the
376 test results shall be reduced by the ratio of the specified thickness of the connector to
377 the measured thickness as shown in equation for the steel strength adjustment factor,
378 R_s , defined in Section 3.2.1.

379 **3.3.2 Connection Strength:**

380 **3.3.2.1** Where the light-frame member(s) is wood, the
381 available strength of the connector fastened to the wood member shall be determined
382 in accordance with the applicable provisions of the NDS when connector strength is
383 based solely on the size and number of fasteners. For connectors of unusual geometry
384 where load transfer in wood bearing occurs in combination with load transfer through
385 fasteners, the connection strength of the cold-formed sheet steel connector shall be
386 determined in general agreement with the test and analysis provisions of the ICC-ES
387 Acceptance Criteria for Joist Hangers and Similar Devices (AC13), with the following
388 modifications:

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

391 (b) The allowable test load determined in accordance with AC13
392 shall be multiplied by the wood connection strength reduction factor, R_{sg} , defined in

393 Section 3.2.2, to account for increased fastener perpendicular-to-grain strength used in
394 the tests.

395 **3.3.2.2** Where the light-frame member(s) is cold-formed
396 steel, the available strength of the connector fastened to steel framing member(s) shall
397 be determined in accordance with applicable provisions of AISI-NAS or the ICC-ES
398 Acceptance Criteria for Connectors Used with Cold-formed Steel Structural Members
399 (AC261), as applicable.

400 **3.3.2.3** Strap style hold-down connectors and foundation
401 anchor strap connectors shall be tested to determine the serviceability limit state for the
402 connector, which shall be the deflection associated with the allowable load determined
403 for the connector based on the test and analysis provisions of Section 3.3.2.1 or
404 3.3.2.2, as applicable, but no greater than the average load at which the deflection of
405 the connector parallel to the application of the test load reaches a serviceability limit
406 state of $\frac{1}{8}$ inch (3.2 mm), unless a different serviceability limit state associated with
407 static deflection can be justified for the connector.

408 **3.3.3 Anchorage Strength:**

409 **3.3.3.1** For cold-formed sheet steel connectors (as defined in
410 Section 1.4.3) designed using Allowable Stress Design (ASD) load combinations in
411 accordance with IBC Section 1605.3, and Load and Resistance Factored Design
412 (LRFD) load combinations in accordance with IBC Section 1605.2, the available
413 anchorage tension strength, T , and the available anchorage shear strength, V , shall be
414 determined using the following equations:

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

436 compressive strength by more than 10 percent, R_c shall
437 equal the value determined in accordance with Section
438 3.2.3. R_c is not cumulative with R_s . The greater reduction
439 factor of R_c or R_s shall be used in the derivation of T or V .

440 R_{cr} = Cracked concrete strength reduction factor. $R_{cr} = 1.0$
441 when an analysis indicates no cracking in the concrete at
442 the location of the connector at service loads, otherwise
443 $R_{cr} = 0.70$. Alternatively, R_{cr} shall be permitted to be
444 increased above 0.70 based on tests in accordance with
445 Section 4.2.

446 R_d = Ductility reduction factor. $R_d = 1.0$ when the connector is
447 used in locations having a seismic design category A or
448 B, otherwise $R_d = 0.75$.

449 R_s = Steel strength reduction factor determined in accordance
450 with Section 3.2.1 using the greater reduction determined
451 for the cold-formed steel framing member or the cold-
452 formed sheet steel connector. R_s is not cumulative with
453 R_c . The greater reduction factor of R_s or R_c shall be used
454 in the derivation of T or V .

455 α = Conversion factor from LRFD to ASD, calculated as
456 either the largest load factor in a load combination used
457 to determine loads to the cold-formed sheet steel
458 connector or a weighted average of the load factors for
459 the controlling load combination to determine ASD

- 460 anchorage loads.
- 461 $\alpha = 1.0$ to determine the anchorage design tension and
- 462 shear strength, T_{LRFD} and V_{LRFD} , respectively.
- 463 In no case shall $N_u \times R_s$ (or $N_u \times R_c$, when $R_c < R_s$)
- 464 divided by the anchorage allowable tension strength,
- 465 T_{ASD} , determined by the equation in Section 3.3.3.1 be
- 466 less than 2.5 for wind or seismic in Seismic Design
- 467 Categories A and B, or 3.5 for seismic in Seismic Design
- 468 Categories C, D, E, and F.
- 469 In no case shall $N_u \times R_s$ (or $N_u \times R_c$, when $R_c < R_s$)
- 470 divided by the anchorage design tension strength, T_{LRFD} ,
- 471 determined by the equation in Section 3.3.3.1 be less
- 472 than 1.5 for wind or seismic in Seismic Design
- 473 Categories A and B, or 2.2 for seismic in Seismic Design
- 474 Categories C, D, E, and F.
- 475 ϕ = Strength reduction factor, which shall be as follows:
- 476 (a) Connector governed by strength of ductile steel:
- 477 (i) Tension loads, $\phi = 0.75$
- 478 (ii) Shear loads, $\phi = 0.65$
- 479 (b) Connector governed by strength of brittle steel:
- 480 (i) Tension loads, $\phi = 0.65$
- 481 (ii) Shear loads, $\phi = 0.60$
- 482 (c) Connector governed by concrete:
- 483 (i) Tension loads (breakout failure), $\phi = 0.75$ when

- 484 supplementary reinforcement provided,
485 otherwise $\phi = 0.70$
486 (ii) Tension loads (pullout failure), $\phi = 0.70$
487 (iii) Shear loads, $\phi = 0.75$ when supplementary
488 reinforcement provided, otherwise $\phi = 0.70$

489 **3.3.3.2** Elongation shall be determined according to a
490 recognized standard. If the elongation is at least 14 percent and the reduction in area is
491 at least 30 percent, the connector shall be considered to meet the ductile steel
492 requirements. If the ductility and reduction of area can not be determined, the connector
493 shall be reported as brittle in the evaluation report.

494 **3.3.3.3** When the cold-formed sheet steel connector is
495 fabricated from brittle steel and the connector is used in Seismic Design Categories C,
496 D, E, and F, either (1) the connection shall undergo ductile yielding at a load level
497 corresponding to anchorage forces no greater than the available connection strength, or
498 (2) or the available anchorage strength shall be reduced by one half.

499 **3.3.3.4** Design strength of steel reinforcement may be used
500 rather than the concrete breakout strength when reinforcement is installed on both
501 sides of the breakout surface or encloses the cast-in connector and is developed
502 beyond the breakout surface using a strength reduction factor, ϕ , equal to 0.75 in the
503 design of the reinforcement.

504 **3.4 Cold-Formed Steel Framing Member:**

505 **3.4.1** If the tensile strength of the steel from which the tested cold-formed
506 framing member is larger than the specified minimum value, the test results shall be
507 calibrated to the specified minimum tensile strength of the steel which the manufacturer

508 intends to use by the steel strength adjustment factor, R_s , defined in Section 3.2.1. The
509 tested steel tensile strength value shall not exceed the specified value by more than 20
510 percent. A similar adjustment shall be made on the basis of yield point instead of
511 tensile strength where yield point is a critical factor.

512 **3.4.2** If the measured thickness of the steel, from which the connector is
513 fabricated, is greater than the specified thickness by more than 5 percent, the test
514 results shall be reduced by the ratio of the specified thickness of the connector to the
515 measured thickness as shown in equation for the steel strength adjustment factor, R_s ,
516 defined in Section 3.2.1.

517 **4.0 TEST METHODS**

518 **4.1 Qualification Testing of Cold-formed sheet steel Connectors Cast-in** 519 **Concrete:**

520 **4.1.1 Testing Machine:** A testing machine that is capable of operation at
521 a constant rate of motion of the movable crosshead or a constant rate of loading, and a
522 force measuring device that is calibrated in accordance with Method ASTM E 4, shall
523 be used.

524 **4.1.2 Concrete Specimen:** Compressive strength of concrete
525 specimens shall be determined in accordance with Section 3.1.3. Concrete specimens
526 shall be formed to be representative of end use applications for cold-formed sheet steel
527 connectors.

528 **4.1.3 Test Sample Size:** Differences in connector size, configuration,
529 and material specifications shall be the basis for establishing a test sample size. A
530 minimum of five connectors for each type of device (size, configuration, and material
531 specifications) shall be tested for each load direction sought for recognition.

532 Connectors shall be tested at the minimum and maximum embedment for which
533 recognition is desired. The coefficient of variation, COV, of the maximum (peak) loads
534 recorded in any test series, including those performed with an increased number of
535 replicates, shall not exceed 15 percent. If the COV does not meet this requirement, the
536 sample size shall be permitted to be increased. If the requirement for maximum
537 coefficient of variation is not met, the cold-formed sheet steel connector shall be
538 considered unqualified.

539 **4.1.4 Test Setup:** Connectors shall be tested individually in such a
540 manner to simulate the essential function of the connector as anchorage to concrete.
541 Connectors shall be attached to a steel jig to try to preclude steel connection failures.
542 The test setup shall be configured to ensure a concrete breakout failure (Section 1.4.4)
543 or a concrete pullout failure (Section 1.4.5). Test loads shall be applied with reference
544 to the intended end-use application of the connector. Low-friction rollers are permitted
545 to be used in the test setup to prevent lateral movement of the steel jig or framing
546 members the connector is attaching due to eccentricity, but shall not attach directly to
547 the connector.

548 **4.1.5 Test Procedure:** An initial load, or preload, shall not be applied for
549 tension (uplift) load or shear (required for sill plate and bottom track anchorage) testing
550 of connectors. The prohibition on applying a preload is based upon the premise that
551 these connectors are designed and installed to resist short-term loading, such as wind
552 or seismic loads, where no settling of the installed connector, induced by the wind or
553 seismic forces, occurs in the loading direction prior to the application of the wind or
554 seismic design loads. Cold-formed sheet steel connectors embedded at locations
555 representative of end use installations in concrete test specimens shall be tested in

556 general agreement with ASTM E 488. When it is necessary to deviate from the ASTM
557 E 488 test method, the test report shall include a clear description of the deviations and
558 the reason for their implementation.

559 **4.2 Connector Testing to Determine Cracked Concrete Reduction Factor:**

560 **4.2.1** These tests are in addition to structural load tests of the connector
561 in the actual installed condition to determine the anchorage strength in accordance with
562 Section 3.3.3. A minimum of 5 tests in the cracked specimen and 5 in the uncracked
563 specimen shall be performed. It is permitted to test the connector in the same product
564 series with shortest embedded portion and the deepest embedded portion to determine
565 the reduction factor(s).

566 **4.2.2** The width and length of the concrete test specimen shall be such
567 so that there is a minimum of 2 times the vertical dimension of the embedded portion
568 (l_e) of the connector on either side along the length of the concrete test specimen
569 measured from the centerline of the connector to each edge. The width of the test
570 specimen shall be such so as the same failure mode occurs as in the installation
571 conditions of the tests conducted in accordance with Section 4.1. The support
572 members shall be no closer than $2l_e$ from the centerline of the connector.

573 **4.2.3** The concrete test specimens shall be formed to be representative
574 of end use applications for cold-formed sheet steel connectors.

575 **4.2.4** A concrete test specimen shall have a minimum 0.012 inch (0.30
576 mm) wide crack induced along the entire depth of the test specimen centered on the
577 connector. The crack width shall be measured as the average of the crack width from
578 one side of the top of the concrete member to the other side of the top of the concrete
579 member. The crack may be induced with an inserted steel plate or with a slight kerf cut

580 or formed groove centered on the connector and then the concrete specimen shall be
581 pulled apart until the specified crack width is achieved. Additional information on
582 cracked concrete test members is available in Section A4 of ACI 355.2. Refer to Figure
583 6.

584 **4.2.5** If a shear test is performed on the connector, the load shall be
585 applied perpendicular to the induced crack when the connector is to be used within 8
586 inches (203 mm) of the edge of the foundation. Otherwise, the load shall be applied
587 parallel to the induced crack for symmetrical connectors. For unsymmetrical
588 connectors further than 8 inches (203 mm) from the edge of concrete, a shear test
589 parallel and a test series perpendicular shall be conducted. Refer to Figures 7 and 8
590 for an example of a tension test setup; however, a similar setup may be used for shear
591 testing.

592 **4.2.6** The cracked concrete reduction factor shall be determined by
593 dividing the connector average maximum (peak) load from the cracked concrete
594 specimen tests by the connector average peak load from the uncracked concrete
595 specimen tests. This factor may be considered to be 1.0 if the difference is less than
596 10 percent.

597 **5.0 QUALITY CONTROL**

598 **5.1** Welded connectors shall be manufactured under an approved quality
599 control program with inspections by an inspection agency accredited by the
600 International Accreditation Service (IAS) or otherwise acceptable to ICC-ES. Third-party
601 follow-up inspections are not required under this acceptance criteria for non-welded
602 connectors.

603 **5.2** Quality documentation complying with the ICC-ES Acceptance Criteria for

604 Quality Documentation (AC10) shall be submitted.

605 **6.0 EVALUATION REPORT RECOGNITION**

606 **6.1** The evaluation report shall describe the cold-formed sheet steel connector
607 with respect to material specifications.

608 **6.2** The evaluation report shall provide a table or table footnotes specifying
609 the following information:

610 **6.2.1** Connector dimensions.

611 **6.2.2** Required fasteners, including type, number, and size, for attaching
612 the connector to the wood or cold-formed steel member. Additionally, a note indicating
613 whether predrilled holes are required.

614 **6.2.3** Required minimum specified concrete compressive strength.

615 **6.2.4** Edge, end and spacing dimension requirements for cast-in
616 connector.

617 **6.2.5** Reinforcement requirements (if used above the embedded portion
618 of the connector in the test program).

619 **6.3** The evaluation report shall include the following statements for connectors
620 used for wood construction:

621 **6.3.1** The allowable loads shown in the product tables of this report are
622 based on allowable stress design and include the load duration factor, C_D ,
623 corresponding with the applicable loads in accordance with the NDS.

624 **6.3.2** Tabulated allowable loads apply to products connected to wood
625 used under dry conditions and where sustained temperatures are 100°F (37.8°C) or
626 less. When products are installed to wood having a moisture content greater than 19
627 percent (16 percent for engineered wood products), or where wet service is expected,

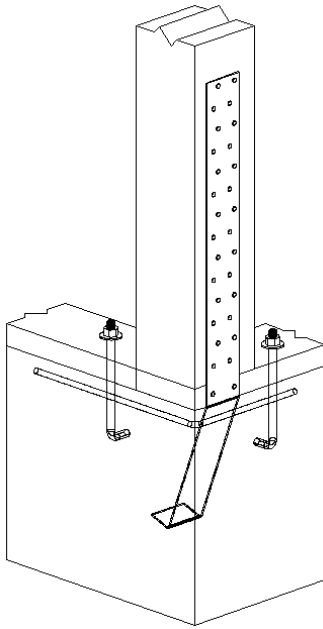
628 allowable loads must be adjusted by the wet service factor, C_M , as specified in the NDS.
629 When connectors are installed in wood that will experience sustained exposure to
630 temperatures exceeding 100°F (37.8°C), the allowable loads in this report must be
631 adjusted by the temperature factor, C_t , specified in the NDS.

632 **6.4** The evaluation report shall include the following statement concerning
633 installation: “Installation of the connectors must be in accordance with this evaluation
634 report and the manufacturer's published installation instructions. In the event of a
635 conflict between this report and the manufacturer's published installation instructions,
636 this report governs.”

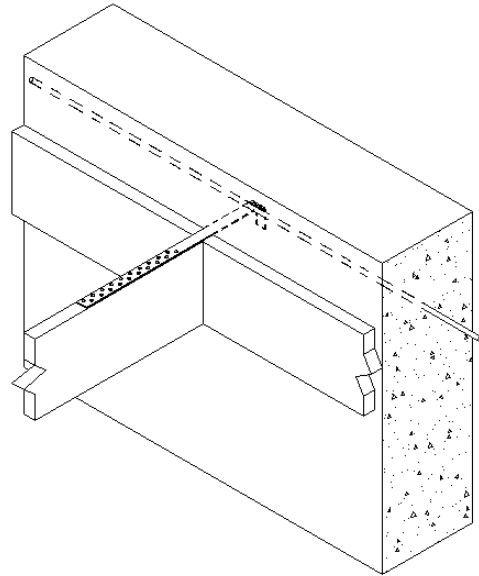
637 **6.5** The evaluation report shall include the following statements when the
638 cast-in-place cold-formed sheet steel connectors are used as components in the
639 building's seismic force resisting system:

640 **6.5.1** For jurisdictions adopting the IBC, periodic special inspection shall
641 be provided for components within the seismic-force-resisting system in Seismic Design
642 Categories C, D, E or F in accordance with Section 1707.3 or 1707.4, with the
643 exception of those structures that qualify under Section 1704.1.

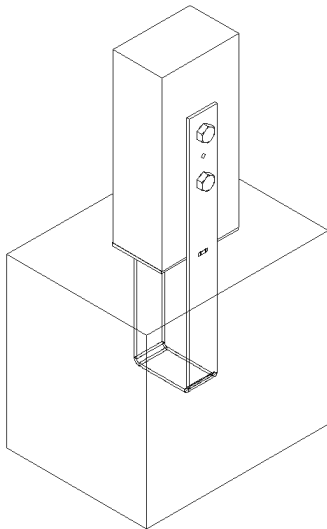
644 **6.5.2** For jurisdictions adopting the IRC, special inspections shall not be
645 required. ■



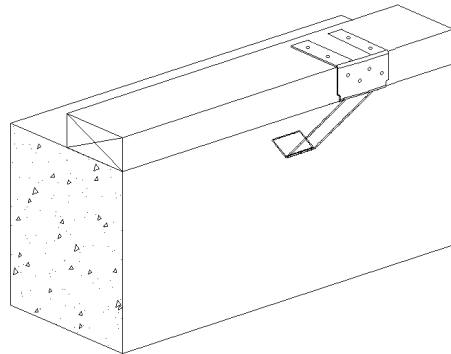
**Figure 1— Example of Strap
Style Hold-down**



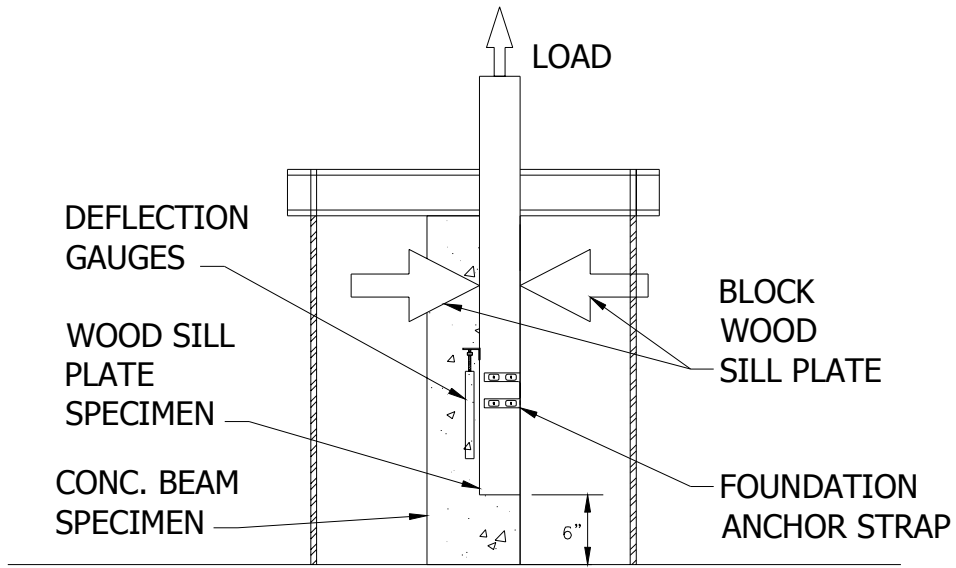
**Figure 2— Example of
Structural Concrete Wall
Connector**



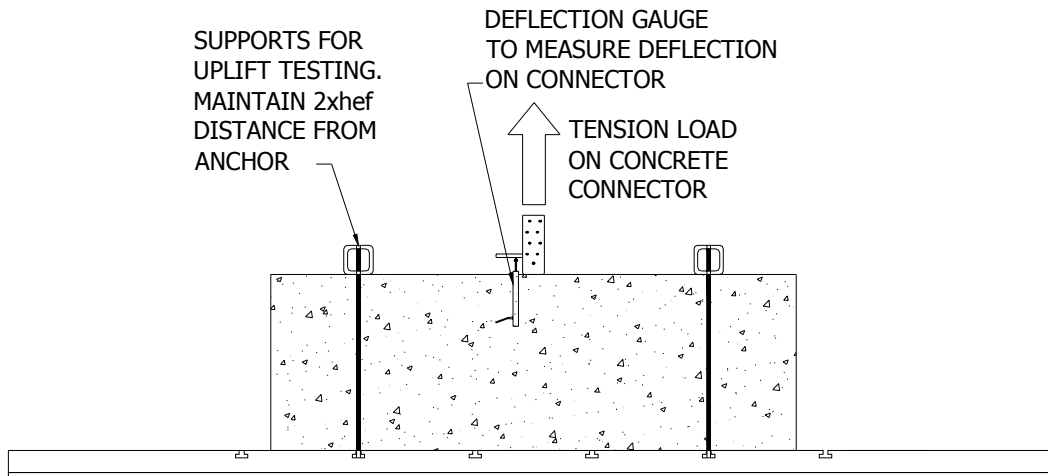
**Figure 3— Example of Column
Base with No Stand Off**



**Figure 4—Example of
Foundation Anchor Strap**

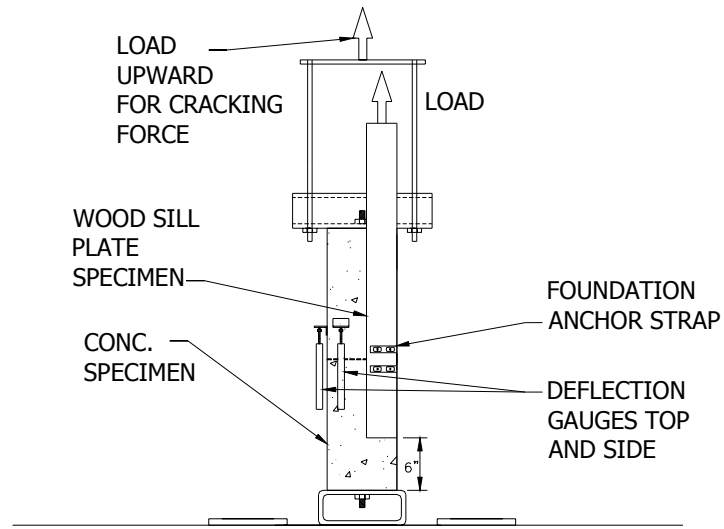


FOUNDATION ANCHOR STRAP SETUP FOR SHEAR

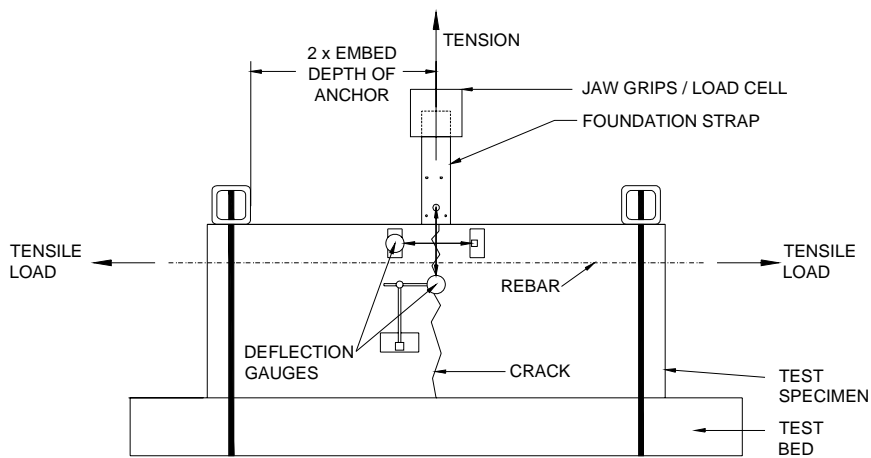


STRAP STYLE HOLDDOWN SETUP FOR TENSION

Figure 5 General Elevations of Non-Cracked Concrete Setups



FOUNDATION ANCHOR STRAP SETUP FOR SHEAR



STRAP STYLE HOLDOWN SETUP FOR TENSION

Figure 6 General Elevations of Cracked Concrete Setups

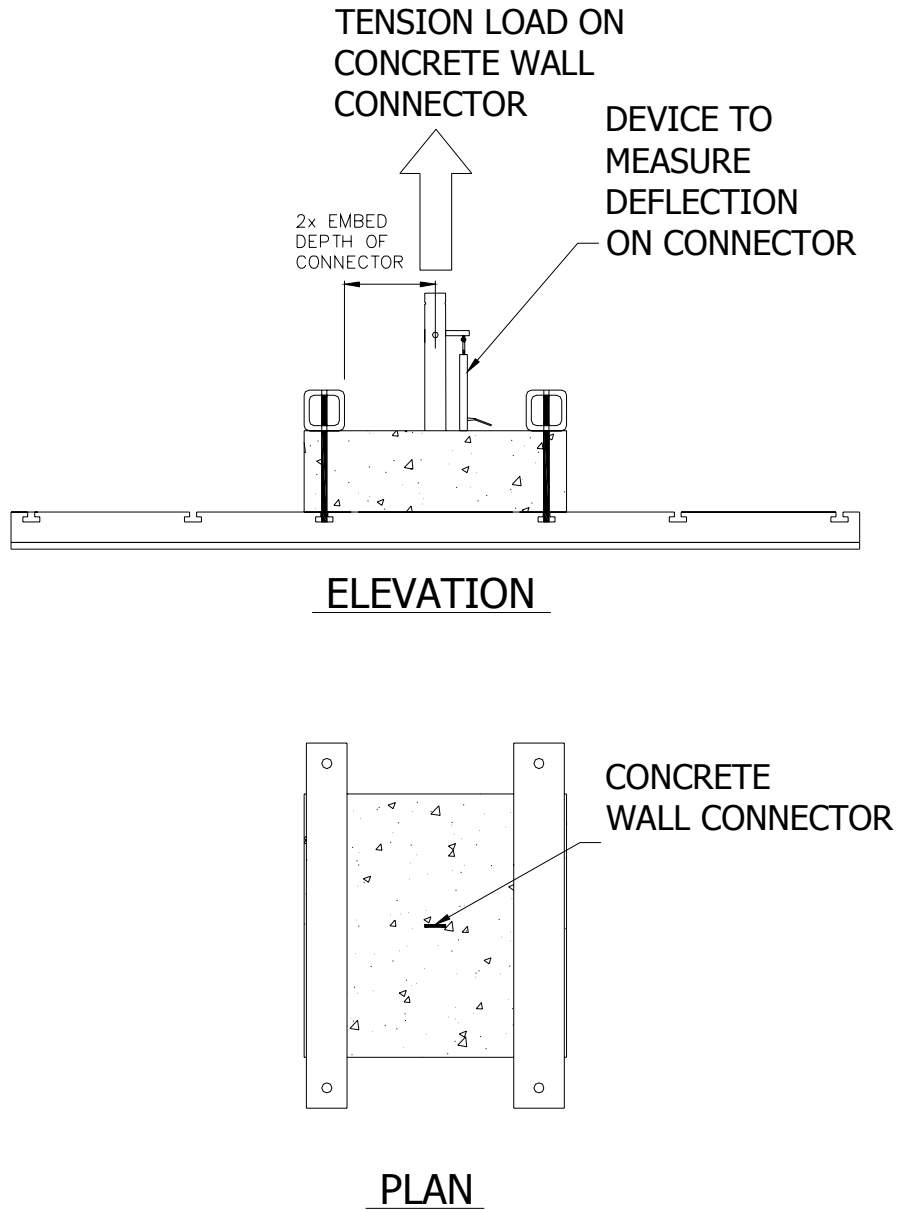


Figure 7 General Plan and Elevation of Structural Wall Connector for Non-Cracked Concrete Test Setup

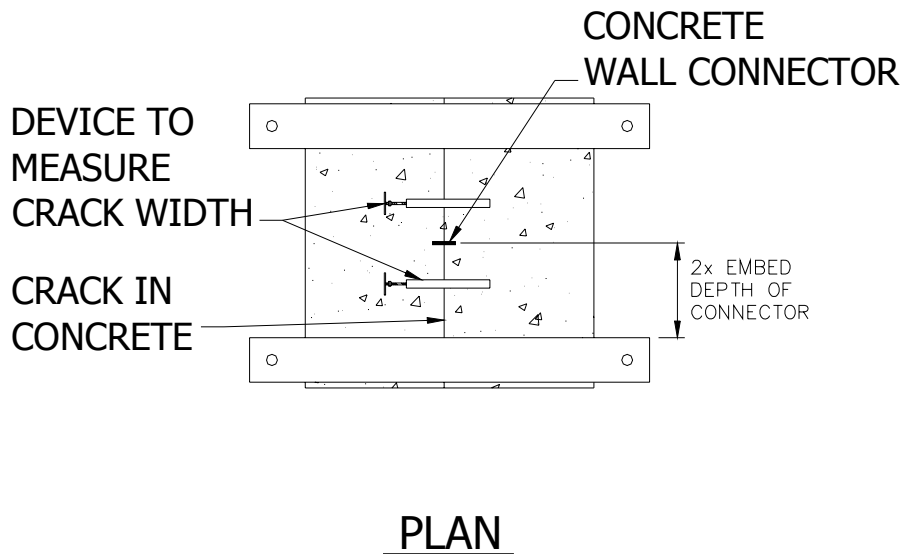
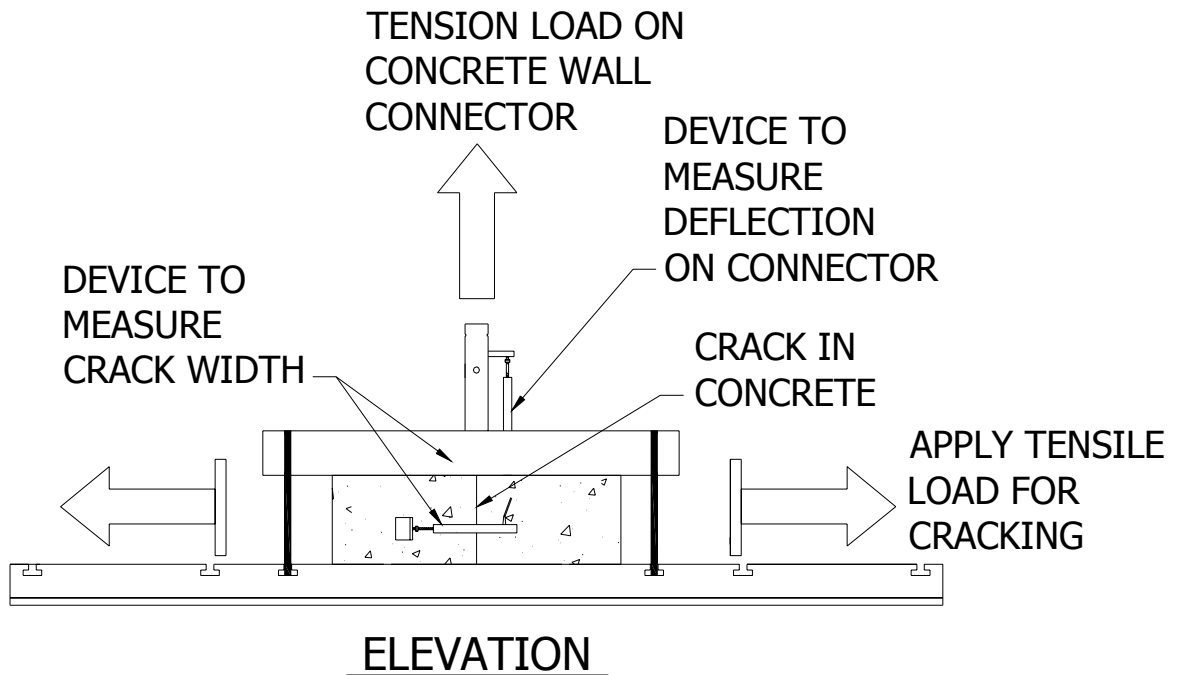


Figure 8 General Plan and Elevation of Structural Wall Connector for Cracked Concrete Test Setup