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ESR-3031

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DIVISION: 05 00 00—METALS
SECTION: 05 12 00—STRUCTURAL STEEL FRAMING

REPORT HOLDER:

CAST CONNEX CORPORATION

366 ADELAIDE STREET EAST, SUITE 425
TORONTO, ONTARIO M5A 3X9
CANADA

EVALUATION SUBJECT:

CAST CONNEX® HIGH-STRENGTH CONNECTORS™



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Section: 05 12 00—Structural Steel Framing**REPORT HOLDER:****CAST CONNEX CORPORATION**
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CANADA
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www.castconnex.com
info@castconnex.com**EVALUATION SUBJECT****CAST CONNEX® HIGH-STRENGTH CONNECTORS™****1.0 EVALUATION SCOPE****Compliance with the following codes:**

- 2009 *International Building Code*® (IBC)
- 2006 *International Building Code*® (IBC)

Properties evaluated:

Structural

2.0 USES

Cast ConneX® High-Strength Connectors™ are used as steel brace-to-gusset plate connections in seismic-resistant steel concentrically braced frame construction. The connectors are also used in non-seismic structural applications as connectors for structural steel elements loaded predominantly in tension and/or compression.

3.0 DESCRIPTION**3.1 General:**

Cast ConneX® High-Strength Connectors™ provide brace-to-gusset plate connections for use in Special Steel Concentrically Braced Frame (SCBF) and Ordinary Steel Concentrically Braced Frame (OCBF) systems as defined in the AISC Seismic Provisions. The connectors are configured as a single-piece element with two parallel flat plates at one end, which transition to a single circular shape at the opposite end. The circular end includes a preparation which forms a 60-degree groove angle between the wall of the round HSS or pipe when mated to the connector. Five connector sizes are available, which are coordinated to fit the outer diameter of standard round hollow structural section (HSS) or pipe sections used to construct the brace: Model HSC-102,

for 4-inch-outside-diameter (102 mm) HSS and pipe; Model HSC-141 for 5⁹/₁₆-inch-outside-diameter (141 mm) HSS and pipe; Model HSC-168 for 6³/₈-inch-outside-diameter (168 mm) HSS and pipe; Model HSC-219 for 8⁵/₈-inch-outside-diameter (219 mm) HSS and pipe; and Model HSC-273 for 10³/₄-inch-outside-diameter (273 mm) HSS and pipe. The connectors must be shop-welded by a registered and approved fabricator to round HSS or pipe brace elements using complete joint penetration (CJP) groove welds; and the resulting brace-connector assembly must be field-bolted or field-welded to single gusset plates connected to the beam-column intersections of a structural steel frame at each end of the brace-connector assembly. The flat plates of the connectors must be prepared with holes by the registered and approved fabricator to allow for bolted connections. Illustrative details are provided in Figures 1, 2, and 3.

3.2 Materials:

3.2.1 Cast ConneX® High-Strength Connectors™: The proprietary connectors are produced by Cast Connex Corporation from cast steel complying with ASTM A958 Grade SC 8620 Class 80/50, including supplementary requirements set forth in Appendix A of ANSI/AISC 358-05s1-09 and additional requirements in the approved quality documentation. The minimum strength properties are $F_y = 50$ ksi (345 MPa) and $F_u = 80$ ksi (552 MPa).

3.2.2 Structural Shapes: Structural steel shapes that must be used in conjunction with Cast ConneX® High-Strength Connectors™ include round hollow structural sections (HSS) conforming to ASTM A500 Grade B or C, and ASTM A501; and pipe conforming to ASTM A53. The HSS and pipe must also comply with requirements in Section 8.2b and either Section 13.2 or Section 14.2 of ANSI/AISC 341-05 (ANSI/AISC 341) for SCBFs or OCBFs, respectively.

3.2.3 Welds: The welded joint between a Cast ConneX® High-Strength Connector™ and the connected HSS or pipe brace member must provide complete joint penetration (CJP). When the brace-connector assembly is to be field-welded to the gusset plate rather than field-bolted, the connection between a Cast ConneX® High-Strength Connector™ and the gusset plate must be made using fillet welds. All welded joints must comply with the requirements stipulated in ANSI/AISC 360-05 (ANSI/AISC 360) and ANSI/AWS D1.1-2004 (ANSI/AWS D1.1). For structures located in Seismic Design Category D, E, or F, welded joints must additionally

comply with requirements stipulated in ANSI/AISC 341 and ANSI/AWS D1.8-2005 (ANSI/AWS D1.8) for demand-critical welded connections. Weld filler metal must comply with Charpy V-Notch (CVN) toughness requirements set forth in Section 7.3, Appendix W and Appendix X of ANSI/AISC 341. As the cast steel material of the connectors is not prequalified as set forth in Chapter 3 of ANSI/AWS D1.1 and heat treatment may include quenching and tempering, welds must be qualified by procedure qualification records in accordance with Chapter 4 of ANSI/AWS D1.1.

3.2.4 Bolts: The high-strength bolts used between the Cast ConneX[®] High-Strength Connector[™] and the gusset plate must comply with ASTM A325, ASTM F1852 or ASTM A490.

3.2.5 Structural Plates: The structural steel material used for the gusset plates must comply with Section A3 of ANSI/AISC 360. For structures assigned to Seismic Design Category D, E, or F, the structural steel material must also comply with Sections 6 and 8.2 of ANSI/AISC 341 and additional requirements, depending on whether the joint is bolted or welded, as set forth in Section 7 of ANSI/AISC 341.

4.0 DESIGN AND INSTALLATION

4.1 SCBF or OCBF System Design:

The structural design procedures must be in accordance with Chapters 16 and 22 of the 2009 IBC or 2006 IBC as Load and Resistance Factor or Allowable Stress Design. The design procedures must also be in accordance with ANSI/AISC 360 and the 2013 Cast ConneX[®] High-Strength Connector[™] Design Guide, 2nd edition. As set forth in IBC Section 2205.2, when used as a portion of the seismic load-resisting system in Seismic Design Category D, E, or F, seismic design and detailing must comply with ASCE/SEI 7-05 and ANSI/AISC 341. The connector must be considered to be within a protected zone and subject to provisions of Sections 7.4 and 13.6 of ANSI/AISC 341.

4.2 Brace Connection Design:

The connections must be designed and detailed in accordance with ANSI/AISC 341 when the assemblage is a portion of a seismic load-resisting system, or ANSI/AISC 360 for non-seismically loaded applications. When used to create an SCBF or OCBF in Seismic Design Category D, E, or F, the connections must develop the required strength in accordance with ANSI/AISC 341, Section 13 or Section 14, respectively. The SCBF design must also comply with the requirements for the exception listed in ANSI/AISC 341, Section 13.3b, as illustrated in Figure 3, or alternatively provide a rationale for using an alternative design and detailing method to ensure that the plastic hinge at a brace end forms within the gusset plate and not within the connector, the connection between the connector and the gusset plate, nor within the brace.

The welded joint between a Cast ConneX[®] High-Strength Connector[™] and the connected hollow section brace member must provide complete joint penetration (CJP).

When the brace-connector assembly is to be field-bolted to the gusset plate, the bolted joint between the Cast ConneX[®] High-Strength Connector[™] and the gusset plate must be designed in accordance with ANSI/AISC 360. For structures located in Seismic Design Category D, E, or F, design must also comply with Section 7.2 of ANSI/AISC 341 using pretensioned

high-strength bolts in joints with slip-critical faying surfaces conforming to Class A or Class B requirements.

When the brace-connector assembly is to be field-welded to the gusset plate, the connection between a Cast ConneX[®] High-Strength Connector[™] and the gusset plate must be made using fillet welds. The design must comply with ANSI/AWS D1.1 with the modifications in ANSI/AISC 360.

4.3 Fabrication and Erection:

The welded joint between a Cast ConneX[®] High-Strength Connector[™] and the connected HSS or pipe brace member must provide complete joint penetration (CJP), and this welding operation must be performed in the shop of a registered and approved fabricator.

A Welding Procedure Specification (WPS), prepared in accordance with Clause 4 of ANSI/AWS D.1 and Section 1704.3.1, Table 1704.3 and Section 1708 of the IBC, must be developed by the steel fabricator for each base steel type, welding position, weld type, welding process, electrode manufacturer, and filler metal trade name for the electrode type selected; and for all essential variable changes set forth in Clause 7.7 of ANSI/AWS D1.1 in the Procedure Qualification Record (PQR) that exceed allowable tolerances. For structures assigned to Seismic Design Categories D, E, and F, the WPS must also comply with supplemental requirements in Clause 6.1 of ANSI/AWS D1.8 and Section 18 and Appendix Q of ANSI/AISC 341. Each WPS must be qualified in accordance with a documented PQR in accordance with Clause 4 of ANSI/AWS D1.1.

Table 1 provides a suggested test WPS for performing PQR, and the related WPS for production, assuming the test WPS is used.

Erection must be in conformance with ANSI/AISC 303-05, Section 7, and must be consistent with the requirements noted in Chapter 22 of the IBC. The brace-connector assembly's connection to the gusset plate using either welds or bolts must be made either at an approved fabricator's shop or at the jobsite by the erector.

4.4 Quality Assurance:

4.4.1 Cast ConneX[®] High-Strength Connectors[™]: Non-destructive testing must be conducted by the manufacturer's qualified inspectors. The procedures for qualification of inspectors must be in accordance with American Society for Nondestructive Testing, Inc. (ASNT), TC-1A or an equivalent standard as set forth in the manufacturer's approved quality documentation. Applicable testing requirements include the following:

4.4.1.1 Tensile Requirements: Tensile tests must be performed for each heat in accordance with ASTM A370 and ASTM A781, and show compliance with requirements for the cast steel grade in accordance with ASTM A958 Grade SC8620 Class 80/50.

4.4.1.2 Charpy V-Notch (CVN) Requirements: CVN testing must be performed for each heat in accordance with ASTM A370 and ASTM A781. Three notched specimens must be tested with the first heat, and with each subsequent 20th ton (18 100 kg) of finished material. The specimens must have a minimum CVN toughness of 20 ft-lb (27 J) at 70°F (21°C).

4.4.1.3 Non-destructive Testing (NDT) of Castings:

4.4.1.3.1 Procedures: Radiographic testing (RT) as set forth in the approved quality documentation is conducted according to the procedures prescribed in ASTM E446

and ASTM E186, with an acceptance of Level III or better. Ultrasonic testing (UT) as set forth in the approved quality documentation is conducted according to the procedures set forth in ASTM A609 Procedure A, with an acceptance of Level 3 or better. Magnetic particle testing (MT) as set forth in the approved quality documentation is conducted according to the procedures prescribed by ASTM E709 with an acceptance of Level III or better in accordance with ASTM A903. Visual inspection as set forth in the approved quality documentation must be performed in accordance with ASTM A802, with an acceptance of Level I.

4.4.1.3.2 Required NDT: First Article: The first article is defined as the first production casting made from a permanently mounted and rigged pattern. First Article Inspection (FAI) must be performed on the first casting produced from each pattern. The first article casting dimensions must be measured and recorded. FAI must include RT and MT.

4.4.1.3.3 Production Castings: UT, MT, and visual inspection must be performed on 100 percent of the casting production.

4.4.1.4 Weld Repair Procedures: Production castings with discontinuities that exceed the requirements of Section 4.4.1.3 of this report must be weld-repaired. Weld-repair of castings must be performed in accordance with ASTM A488. The same testing method that discovered the discontinuities must be repeated on repaired castings to confirm the removal of all discontinuities that exceed the requirements of Section 4.4.1.3 of this report.

4.4.2 Fabrication and Installation of Brace-Connector Assemblies:

4.4.2.1 Fabrication of Brace-to-Connector Assemblies: Cast ConneX[®] High-Strength Connectors[™] are supplied by Cast Connex Corporation. Fabrication of brace-connector assemblies must be performed by a registered and approved fabricator. The approved fabricator must comply with Section 1704.2.2 of the IBC. For structures assigned to Seismic Design Category C, D, E or F, visual inspection and non-destructive testing (NDT) in accordance with Sections 1704 and 1707 of the IBC must be performed. A visual inspection and testing program must be established by the registered design professional and must include the following items, at a minimum:

- a. Visual and Ultrasonic testing of Complete Joint Penetration (CJP) groove welds between the Cast ConneX[®] High-Strength Connector[™] and the round HSS or Pipe brace element in accordance with Appendix Q, Section Q5, of ANSI/AISC 341. This inspection and testing is to be conducted at the shop of the fabricator.
- b. Qualification of NDT personnel, and compliance with ANSI/AWS D1.1 Clause 6.14.6 and ASTM E164, as appropriate.

4.4.2.2 Jobsite: The approved construction documents for each project must include a written quality assurance program, which, at a minimum, must include the following:

- A statement of special inspection complying with IBC Sections 1705, 1706, and 1707 must be included in the structural design drawings and specifications prepared by the registered design professional.
- Special inspection provisions for steel construction must comply with Sections 1704.2, 1704.3 and

1707.2 of the IBC and Part 1, Section 18 and Appendix Q of ANSI/AISC 341, and must be included in the statement of special inspection.

- Special inspection must verify compliance of steel with specifications, steel identification, and identification of high-strength bolts, nuts, washers, if applicable, in accordance with IBC Section 2203 and the approved construction documents.
- When the brace-connector assembly is to be field-bolted to the gusset plates, inspection of high-strength bolt installation must comply with IBC Section 1704.3.3 and Appendix Q, Section Q5.3, of ANSI/AISC-341.
- When the brace-connector assembly is to be field-welded to the gusset plates, special inspection must verify weld filler metal compliance with specifications, weld filler metal identification, qualification of welders, use of appropriate welding materials, storage conditions for welding materials, welded joint preparations, conformance of welding procedures with applicable ANSI/AISC 341 and ANSI/AWS D1.1 requirements, and fabrication tolerances. For structures assigned to Seismic Design Categories C, D, E and F (IBC or ASCE/SEI 7), visual inspection and non-destructive testing (NDT) in accordance with Sections 1704 and 1707 of the IBC must be performed. A visual inspection and testing program must be established by the registered design professional in the statement of special inspection and must include the following items, at a minimum:
 - Visual inspection of all fillet welds between the Cast ConneX[®] High-Strength Connector[™] and the gusset plate in accordance with Appendix Q, Section Q5, of ANSI/AISC 341.
 - Qualification of NDT personnel, and compliance with ANSI/AWS D1.1 Clause 6.14.6 and ASTM E164, as appropriate.

5.0 CONDITIONS OF USE:

The Cast ConneX[®] High-Strength Connectors[™] described in this report comply with, or are suitable alternatives to what is specified in, those codes listed in Section 1.0 of this report, subject to the following conditions:

- 5.1** Connection design must be in accordance with this report, the applicable code, and the "Cast ConneX[®] High-Strength Connector[™] Design Guide," and must be prepared by a registered design professional.
- 5.2** Structural design drawings and specifications, shop drawings, and erection drawings must comply with Section A4 of ANSI/AISC 360 and Section 5 of ANSI/AISC 341.
- 5.3** Fabrication and erection of brace-connector assemblies must comply with Sections 4.3 and 4.4 of this report and the "Cast ConneX[®] High-Strength Connector[™] Design Guide," and must either be done by a fabricator approved by the building official, as set forth in Section 1704.2.2 of the IBC, or must be under special inspection as set forth in Section 1704 of the IBC.
- 5.4** Quality assurance must be provided in accordance with Section 4.4 of this report.

6.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Acceptance Criteria for Cast ConneX[®] High-Strength Connectors[™] for Use

as Bracing Connections in Accordance with AISC 341 Sections 13.3 and 14.4 (AC427), dated October 2011.

7.0 IDENTIFICATION

Each Cast ConneX[®] High-Strength Connector[™] as described in this report is identified by raised markings on the connector that show the manufacturer’s logo (a stylized “X”); the connector name in metric diameter size [for example, HSC-168 corresponds to a Cast ConneX[®] High-Strength Connector[™] accommodating hollow

section elements of 6⁵/₈ inches (168 mm) outer diameter]; and a serial number which provides traceability to heat number, chemical and physical analysis reports, and reports of non-destructive testing. Product labeling includes the report holder’s name, the manufacturer’s name and address, the evaluation report number (ESR-3031) and the name of the inspection agency (ICC-ES LLC).

TABLE 1—SUGGESTED TEST WPS FOR PERFORMING PQR

RECOMMENDATIONS FOR PQR	RECOMMENDATIONS FOR WPS (see ANSI/AWS D1.1:2010 Tables 3.6, and 4.5)
ASTM A958 SC8620 80/50 to ASTM A500 grade B	no change
Thickness: 5/16"	5/32" to 5/8"
Weld type: TYK single bevel CJP groove weld (see AWS D1.1:2010 Figure 3.8 and 3.9, Detail A)	no change
Position: test both 2G and 5G	all
Root Opening: 1/8"	+/- 1/16" (1/16" - 3/16")
Groove Angle: 60 degrees	+ 10, - 5 degrees (55 – 70 degrees)
Process: FCAW-G	no change
Filler Metal Manufacturer: Lincoln Electric Co.	no change
Product Name: UltraCore 71A85	no change
Classification(s): E71T-1M-H8, E71T -9M-H8	no change
Diameter: 0.045"	no change
Shielding Gas: 80% Argon, balance CO2	75-85% Argon, balance CO2
Shielding Gas Flow Rate: 45 CFH	+ 30%, - 20% (36 – 58 CFH)
Current and Polarity: DC+	no change
Output: CV	no change
Contact Tube to Work Distance: 1"	+/- 1/4" (3/4" - 1 1/4")
Voltage: 26 V	+/- 7% (24.2 – 27.8 V)
Amperage: 190 A	+/- 10% (171 – 209 A)
Wire Feed Speed: 350 ipm	+/- 10% (315 – 385 ipm)
Travel Speed: 6 ipm	+/- 25% (5.5 – 7.5 ipm)
Heat Input: (Voltage * Amperage * 0.06 / Travel Speed) = 49 kJ/inch	+ 0, - 20 kJ/inch (29 – 49 kJ/inch)
minimum preheat: 225F	no change
Measured PQR preheat and interpass temperatures	+ not to exceed maximum interpass temperature - 25 degrees
maximum preheat and interpass temperature: 400F	no change
<p>Notes: For the physical properties and bend tests of the completed weld, plate testing similar to Figure 4.11 of ANSI/AWS D1.1:2010, with a 60 degree single bevel groove weld shall be conducted. The test plates for the ASTM A958 SC8620 80/50 material can be supplied by Cast Connex Corporation.</p> <p>For the ASTM A500 material, the test plates shall be cut from the flat side of a large box tube of the same specification and grade of steel being used for the brace (for round HSS braces), or of a flattened section of cut pipe wall.</p>	

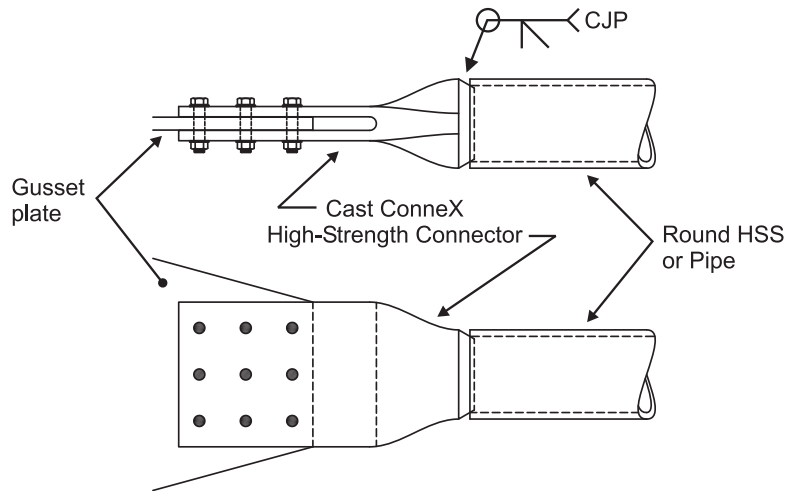


FIGURE 1—CAST CONNEX HIGH-STRENGTH CONNECTOR



FIGURE 2—CAST CONNEX[®] HIGH-STRENGTH CONNECTOR[™] SHOWN IN FIELD-BOLTED CONFIGURATION IN BRACED FRAME

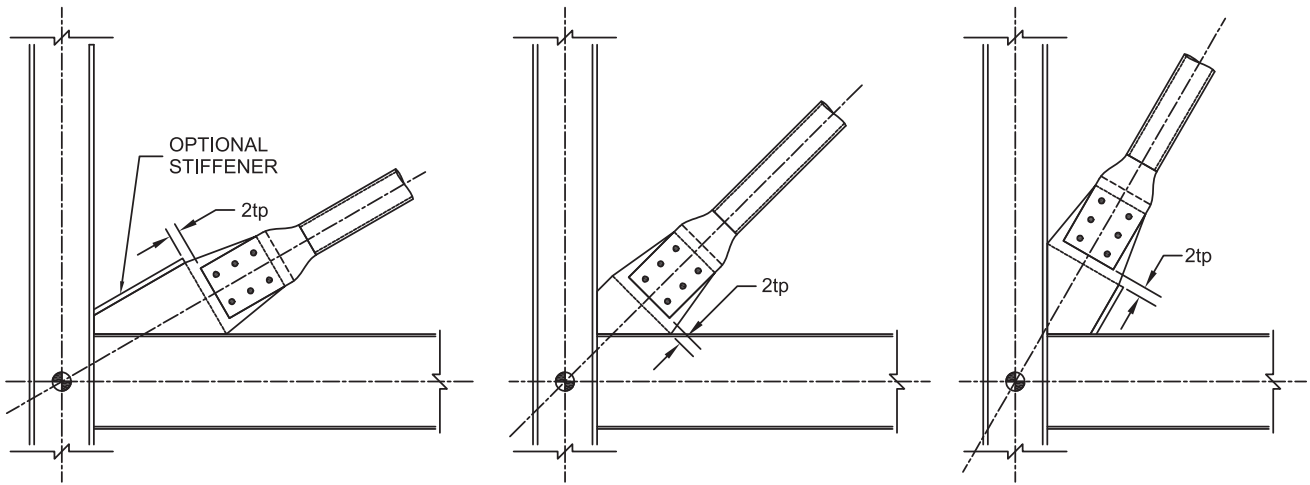


FIGURE 3—GUSSET PLATE DETAILING IN SCBF TO ACCOMMODATE OUT-OF-PLANE INELASTIC DEFORMATION OF BRACE FOR VARIOUS BRACING ANGLES