ICC EVALUATION SERVICE

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February 18, 2010

TO: **PARTIES INTERESTED IN EVALUATION REPORTS ON COLD-FORMED STEEL STRUCTURAL BEAMS ACTING COMPOSITELY WITH CAST-IN-PLACE CONCRETE SLABS**

SUBJECT: Acceptance Criteria for Cold-formed Steel Structural Beams Acting Compositely With Cast-in-place Concrete Slabs, Subject AC425-0210-R1 (DZ/PB]

Dear Madam or Sir:

Enclosed is a copy of the subject new acceptance criteria approved by the ICC-ES Evaluation Committee on February 3, 2010, effective March 1, 2010.

This acceptance criteria applies to hybrid beams, which consist of concrete-filled CFS U-shaped sections and cast-in-place concrete slab. Minimum $^{3}/_{16}$-inch-thick (4.8 mm) flat-rolled carbon steel is cold-formed into C-shapes, with one of the flanges reinforced with curved lip stiffeners. Two resulting C-shapes are welded together face-to-face at the lip stiffeners to create a CFS U-shaped section. The CFS U-section and cast-in-place concrete slab are interconnected by mechanical connectors (headed stud shear connectors) to act as a composite structural flexural member. The structural design and the corresponding verification testing of the hybrid beams are covered by this acceptance criteria.

This acceptance criteria is limited to hybrid beams that are simply supported by code-compliant structural steel columns. Recognition of hybrid beams in an ICC-ES evaluation report is for supporting gravity loads only.

If you have any questions, please contact David Zhao, S.E., Senior Staff Engineer, at (800) 423-6587, extension 3722. You may also reach us by e-mail at es@icc-es.org.

Yours very truly,

Gary G. Nichols

Gary G. Nichols, P.E., SECB
Vice-President

GGN/DZ/jw:raf

Enclosure

cc: Evaluation Committee

ICC EVALUATION SERVICE

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ACCEPTANCE CRITERIA FOR COLD-FORMED STEEL STRUCTURAL BEAMS ACTING COMPOSITELY WITH CAST-IN-PLACE CONCRETE SLABS

AC425

Approved February 2010

Effective March 1, 2010

PREFACE

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

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

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

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

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

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

ACCEPTANCE CRITERIA FOR COLD-FORMED STEEL STRUCTURAL BEAMS ACTING COMPOSITELY WITH CAST-IN-PLACE CONCRETE SLABS (AC425)

1.0 INTRODUCTION

1.1 Purpose: The purpose of this acceptance criteria is to establish requirements for cold-formed steel (CFS) structural beams acting compositely with cast-in-place concrete slabs (hereafter referred to as the hybrid beams) to be recognized in an ICC Evaluation Service, Inc. (ICC-ES), evaluation report under the 2009 *International Building Code*® (IBC). The basis of recognition is IBC Section 104.11.

The reason for the development of this criteria is to provide guidelines for the evaluation of cold-formed steel structural beams acting compositely with cast-in-place concrete slabs, where the codes lack guidance on determination of available strengths, reliability and serviceability of these hybrid beams and details of verification testing.

1.2 Scope: This acceptance criteria applies to the hybrid beams which are proprietary shaped cold-formed steel structural beams fabricated at an approved manufacturing facility with quality control inspections performed by an independent, approved inspection agency. The structural design and the corresponding verification testing of the hybrid beams are covered by this acceptance criteria. This acceptance criteria is limited to hybrid beams that are simply supported by code-compliant structural steel columns. Recognition of hybrid beams in an ICC-ES evaluation report is for supporting gravity loads only. When hybrid beams require fire-resistance protection, compliance with IBC Section 703 is necessary.

1.3 Codes and Referenced Standards:

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

1.3.2 ACI 318-08, *Building Code Requirements for Structural Concrete,* American Concrete Institute.

1.3.3 AISC 303-05, *Code of Standard Practice for Steel Buildings and Bridges*, March 18, 2005, American Institute of Steel Construction.

1.3.4 AISC 360-05, *Specification for Structural Steel Buildings*, American Institute of Steel Construction.

1.3.5 AISI S100-07, *North American Specification for the Design of Cold-formed Steel Structural Members*, American Iron and Steel Institute.

1.3.6 AISI S200-07, *North American Standard for Cold-formed Steel Framing – General Provisions*, American Iron and Steel Institute.

1.3.7 ASCE/SEI 7-05, *Minimum Design Loads for Buildings and Other Structures, Including Supplement No. 1 and 2, excluding Chapter 14 and Appendix 11A*, American Society of Civil Engineers.

1.3.8 ASTM A 370-05**,** Standard Specification for Standard Test Methods and Definitions for Mechanical Testing of Steel Products**,** ASTM International.

1.3.9 ASTM C 31/C31M-06, Standard Practice for Making and Curing Concrete Test Specimens in the Field, ASTM International.

1.3.10 ASTM C 33-03**,** Standard Specification for Concrete Aggregates, ASTM International.

1.3.11 ASTM C 39/C39M-05^{e1}, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, ASTM International.

1.3.12 ASTM C 387-06a, Standard Specification for Packaged, Dry, Combined Materials for Mortar and Concrete, ASTM International.

1.3.13 ASTM E 119-07, Test Methods for Fire Tests of Building Construction and Materials, ASTM International.

1.3.14 ASTM E 575-05, Standard Practice for Reporting Data from Structural Tests of Building Constructions, Elements, Connections, and Assemblies, ASTM International.

1.3.15 AWS D1.1-04, *Structural Welding Code—Steel*, American Welding Society.

1.3.16 AWS D1.3-98, *Structural Welding Code—Sheet Steel*, American Welding Society.

1.3.17 UL 263-03, *Standard for Fire Test of Building Construction and Materials,* Underwriters Laboratories Inc.

1.4 Definitions: Definitions in the IBC, AISC 360, AISC 303, AISI S100, AISI S200 and ACI 318 apply to this criteria. The following definitions, with revisions and amendments to the code provisions, also apply to this criteria:

1.4.1 Full Interaction: The composite action, due to the mechanical connectors, between steel and concrete, such that there is no measureable relative movement (slip) at the steel/concrete interface. Full interaction is a stiffness criterion and relates to compatibility of deformation at steel/concrete interface.

1.4.2 Full Shear Connection: The composite action, due to the mechanical connectors, between steel and concrete, such that the shear connection strength exceeds the tensile yield strength of the steel section or the compression strength of the steel section and/or concrete, so the flexural strength of the composite section can be fully developed. Full shear connection is a strength criterion and relates to equilibrium of forces within a composite member.

1.4.3 Hybrid Beams: The hybrid beams consist of concrete-filled CFS U-shaped sections and cast-in-place concrete slab. Minimum $^{3}/_{16}$-inch- (4.8 mm) thick flat-rolled carbon steels are cold-formed into C-shapes with one of the flanges reinforced with curved lip stiffeners. Two resulting C-shapes are welded together face-to-face at the lip stiffeners to create a CFS U-shaped section. The CFS U-section and cast-in-place concrete slab are interconnected by mechanical connectors (headed stud shear connectors) to act as a composite structural member. Figure 1 provides a typical hybrid beam construction.

1.4.4 Hybrid Beam Fabricator: An entity that fabricates the CFS portions of the hybrid beams, as defined in Section 1.4.3, at an approved fabrication facility. Refer to Sections 5.1, 5.2 and 5.3 for requirements to be included in the ICC-ES evaluation report.

1.4.5 Hybrid Framing: A structural framing system composed of hybrid beams, as defined in Section 1.4.3, and code-compliant structural steel columns, together with proper simple connections (as defined in AISC 360 Section B3.6a) between the hybrid beams and the steel columns so as to form a complete structural assembly designed to support gravity loads only.

1.4.6 Limit State: Condition in which a structure or component becomes unfit for service and is judged either to be no longer useful for its intended function (serviceability limit state) or to have reached its ultimate (peak) load-carrying capacity (strength limit state); or an event in which a slight disturbance in loads or geometry produces large displacements.

1.4.7 Mechanical Connector (Shear Connector): Mechanical connectors are headed studs complying with AISC 360 Sections A3.6 and I1.3, welded to the top flanges of the cold-formed steel structural beams and embedded in the concrete slabs. The design and use of the headed studs ensures composite action between the cold-formed steel and the concrete slabs.

2.0 BASIC INFORMATION

2.1 General: The following information shall be submitted to ICC-ES as part of the information package for obtaining an ICC-ES evaluation report:

2.1.1 Product Description: A detailed description of the cold-formed steel (CFS) structural beams, including information concerning material specifications, dimensions, the manufacturing process, the fabrication tolerances, and restrictions or limitations on use. Information shall be provided on, but shall not be limited to, the following items:

(1) CFS sections: referenced ASTM specifications, grades, shapes, uncoated minimum base steel thickness, detailed cross-sectional dimensions including lip stiffeners and cross-sectional properties.

(2) Shear connectors: types, grades, sizes, locations, spacing and welding requirements. The connectors shall comply with AISC 360 Sections A3.6 and I1.3.

(3) Welding: the applicable welding codes (AWS D1.1 and AISC 360) for welding between CFS sections; welding process; filler metal requirements (AWS electrode specification and electrode classification); welding specification procedure (WPS) if not prequalified in accordance with the applicable welding code; and welding details including type, size, length and locations.

(4) Miscellaneous items: Embedded plates and shapes and bolts, and other connections, shall be defined with corresponding reference standards (such as ASTM) and applicable installation requirements.

2.1.2 Packaging and Identification: A description of the method of packaging and field identification of the hybrid beams. Each hybrid beam shall have a legible label, stamp or embossment, indicating the fabricator's name, report holder's name, the ICC-ES evaluation report number (ESR-xxxx) and the name or logo of the approved inspection agency.

2.1.3 Installation Instructions: Instructions shall include the following items: (1) a description of how the product or system will be used or installed at the project site, including field preparation methods noted in item 5 of Section 2.1.3, below; (2) procedures for quality control at project sites during installation; (3) requirements for product handling as identified in Section 6.6 of this criteria; (4) welding, bolting or connector installation to structural elements, if required; and (5) methods of field modifications such as cutting or bending, if applicable, surface preparation, application and finishing. Field preparation shall be subject to approval of the registered design professional and the code official.

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

2.3 Test Reports: Test reports shall comply with AC85. Detailed descriptions of the test setups, test methods and test procedures, including load application rate, shall be provided in the test report. Information as described in ASTM E 575 shall be included in the test reports.

2.4 Product Sampling: Sampling of the hybrid beams for tests under this criteria shall comply with Section 3.1 of AC85. The fabrication of the test assemblies shall be witnessed by or verified by the testing laboratory.

3.0 STRUCTURAL DESIGN AND TEST REQUIREMENTS

3.1 General: The structural design method and requirements prescribed in Section 3.0 (Subsections 3.2 and 3.3) is a rational engineering analysis as described in AISI S100 Section A1.2 (b) and IBC Section 1604.4, which shall be confirmed by the verification tests prescribed in Section 4.0 in accordance with conditions of acceptance described in Section 3.5.1 or 3.5.2. The requirements for final submittal to ICC-ES for an evaluation report are described in Section 3.4.

3.2 Structural Design Method: The structural design method for determining the available strength of the hybrid beams shall include the flexural strength (Section 3.2.1) and shear strength (Section 3.2.2) and beam stiffness (Section 3.2.3), and shall satisfy structural design requirements described in Section 3.3.

3.2.1 Flexural Strength: The available flexural strength of the hybrid beams (composite action) shall be based on the Strain-Compatibility Method, as specified in AISC 360 Section I1.1b. This method is based on the design assumptions identified in ACI 318 Section 10.2; with the amendment that ACI 318 Section 10.2.4 also applies to the CFS sections.

3.2.2 Shear Strength: The available shear strength of the hybrid beams shall be determined based upon the properties of CFS sections alone in accordance with AISC 360, Chapter G, including Section G2.1 (b).

3.2.3 Hybrid Beam Stiffness: The proposed engineering design of the hybrid beams shall include provisions for calculating deflections of the hybrid beams, including both immediate deflection and long-term deflection. Determination of hybrid beam stiffness (flexural stiffness and shear stiffness, if applicable) shall include effects of slip due to shear connectors, concrete creep, and shrinkage, as identified in Section L3 of AISC 360.

3.3 Structural Design Requirements: The structural design method of the hybrid beams, described in Section 3.2, shall address the following items:

3.3.1 A complete description of a typical hybrid framing assembly as identified in Section 1.4.5.

3.3.2 Details on how the hybrid beams comply with Chapters 19 (with reference to ACI 318) and 22 (with reference to AISC 360 and AISI S100) of the IBC, including conformities and deviations. Details shall clarify the following: (1) the sections of Chapters 19 and 22 of the

IBC with which the hybrid beams comply; (2) the sections of Chapters 19 and 22 of the IBC with which the hybrid beams do not comply; and (3) the sections of Chapters 19 and 22 of the IBC with which the hybrid beams comply but only with revisions and/or amendments, along with revisions and/or amendments identified in the structural design process, as described in Section 3.3.4.

3.3.3 The concrete slab-to-CFS interface shall comply with the requirements for either full interaction or full shear connection, as defined in Section 1.4. The hybrid beams shall be proportioned such that the flexural compressive stress is resisted by the concrete slab only.

3.3.4 A complete description of the proposed structural design method (process), which shall provide detailed steps and examples, including engineering plans and calculations, showing how the hybrid beams are analyzed and designed for strengths and stiffness. The description shall include formulas, with procedures and properties necessary for design and analysis.

3.3.5 The structural design shall specify design provisions for each applicable limit state, including, but not limited to, the following: (1) compression failure of the concrete slab; (2) tension yielding of the CFS section; (3) strength and stiffness limits of the shear connectors; (4) concrete bearing failure resulting from concentrated dowel loads imposed by the shear connectors; and (5) welding yielding or fracture between two CFS sections and yielding or facture of welds attaching shear connectors to the CFS, which shall not be the governing limit state.

3.3.6 Strength and stability of the cold-formed steel (CFS) structural beams during construction. When temporary shores are not used during construction, the CFS structural beams alone shall have adequate strength and stability to support all loads without yielding, local buckling of compression flange or webs, or lateral-torsional buckling, prior to the concrete attaining 75 percent of its specified compressive strength. The available strength of the CFS structural beams such as flexural, shear and web crippling, shall be determined according to AISI S100, Chapter C, shall be sufficient to support the design load prior to the concrete attaining 75 percent of its specified compressive strength.

3.3.7 For structural calculations generated by computer software program, a user's guide to the program shall be submitted. Also, a program description shall be provided and contain the necessary information to enable ICC-ES to determine the nature and extent of the analysis, verify the input data, interpret the results, determine whether the computations fit the design and comply with the code. The description of the output computed by the program shall be clearly distinguished from the data that is input. A general program operation description is also needed, in the form of a flow arrangement of all of the steps taken and the design formulas used, in order to verify compliance with the design method. Hand calculations are needed for each type of hybrid beam, as a minimum, demonstrating that the computer-based results are verifiable.

3.3.8 A complete description of the applicable ranges (minimum and maximum) of the design parameters for the hybrid beams, such as CFS specifications and material grades, CFS thickness, CFS-section width and depth, shear connector size, concrete specified compressive strength, concrete slab thickness, concrete slab at one side only or at both sides, and the spacing between hybrid beams (confirmed by Sections 3.0 and 4.0).

3.3.9 Structural design drawings and specifications, shop drawings and erection drawings shall comply with Sections A4 and M1 of AISC 360, AISC 303, Section 1.2 of ACI 318, and Section 1603 of the IBC.

3.4 Test Reports and Design Criteria Reports:

3.4.1 The final submittal to ICC-ES for an ICC-ES evaluation report shall consist of all necessary test reports (Section 3.4.2) and a design criteria report (Section 3.4.3). The final submittal shall include the data described in Sections 2.1, 2.3, 3.2, 3.3 and 4.0. Contents of the final submittal are described in the following subsections:

3.4.2 Reports of tests for structural performance, including the verification tests (Sections 4.3, 4.4 and 4.5) and material tests (Section 4.2) performed according to the approved test plan described in Section 4.1 shall be submitted. Reports of tests for fire-resistance rating according to Section 4.6 shall be submitted, if required. In addition to the information required in Sections 2.1 and 2.3 of this criteria, each report (of structural performance testing) shall include the following:

3.4.2.1 Information noted in the referenced standards.

3.4.2.2 Description of test specimens.

3.4.2.3 Description of test setups.

3.4.2.4 Rate and method of loading.

3.4.2.5 Load, deformation and strain measurements.

3.4.2.6 All applicable limit states, including modes of failure.

3.4.2.7 Geometrical and mechanical properties of test specimens (CFS, concrete, shear connectors and welding).

3.4.3 A design criteria report shall be submitted and include at a minimum a complete analysis and interpretation of the verification test results presented in the independent laboratory test reports conducted in accordance with Section 4.0. This analysis of test data shall be based on a statistical approach that accounts for the number of specimens such as the procedure described in Section F1.1 (b) of AISI S100. The nominal strength, as specified in Sections B3.3 and B3.4 of AISC 360, and stiffness used for deflection calculation as required by Section L3 of AISC 360, Sections 17.2.7 and 9.5 of ACI 318, and Section 1604 of the IBC for the hybrid beams, shall be predicted in accordance with Sections 3.2 and 3.3, using the material properties determined according to Section 4.2. The predicted nominal strength and stiffness in accordance with Sections 3.2 and 3.3 shall comply with the conditions of acceptance specified in either Section 3.5.1 or Section 3.5.2.

3.5 Conditions of Acceptance:

3.5.1 Acceptable Design Criteria: The predicted (theoretical) nominal strength (flexural and shear) and beam stiffness in accordance with Section 3.4.3, shall be compared to the verification test data and shall comply with the following requirements:

P_m > 1.0 for strength and stiffness; and
V_p < 0.06 for strength only

where:

R_t = Tested capacity for each specimen.

R_a = Predicted nominal capacity for each specimen in accordance with Section 3.4.3 and without the adjustment by resistance factor or safety factor.

P = Ratio of the tested capacity to the predicted capacity (professional factor), R_t/R_a.

P_m = Average (mean value) of the P values of identical specimens.

V_p = Coefficient of variation of the P values of identical specimens.

3.5.2 Alternate Acceptable Design Criteria: As an alternate to requirements described in Section 3.5.1, design provisions, including formulas, shall be revised to justify that the reliability index (or safety index) of hybrid beams for each limit state, with adjustments to the code-prescribed resistance factor, safety factor or both, using the verification test values, shall be equal to or greater than the code-intended requirements, which are clarified in the commentary to Section B3.3 of AISC 360.

4.0 TEST METHODS

4.1 Verification Test Plan (for Structural Performance):

4.1.1 General: The intent of the verification tests is to verify the adequacy and reliability of the design equations and assumptions used in the proposed rational engineering analysis described in Section 3.0. All tests described and specified in a verification test plan shall be submitted to ICC-ES staff for approval prior to testing. The test plan shall be a complete document, which includes, at a minimum, the conformation details noted in this section.

Specific verification testing must provide data on material geometrical and mechanical properties and, force and deformation limit states, including failure modes, to demonstrate the actual strength is not less than the nominal strength (resistance) predicted by the rational engineering analysis procedure for the type of behavior involved. The specimens shall be constructed to simulate the end use conditions; refer to Section 3.3.8 for applicable ranges of design parameters. Concrete construction shall be in accordance with ACI 318 and Section 4.2 of this criteria. Sampling of the specimens shall be in accordance with Section 2.4. Tests shall simulate the anticipated loading conditions, loading rates, load levels, deflections, and support conditions, and shall be conducted to failure for the applicable limit states or otherwise be able to determine the available strengths and stiffness. As a minimum, verification tests shall be conducted for the following limit states: flexural (Section 4.3), shear connectors (Section 4.4), and shear (Section 4.5).

4.1.2 Test Specimens: Full-scale specimens shall be used for verification tests. Tests shall be conducted to failure on a minimum number of three identical specimens for flexural (Section 4.3), shear connectors (Section 4.4), and shear (Section 4.5), respectively. Test results shall be evaluated based on the average value of test data on identical specimens. The deviation of any individual test result from the average value obtained from all tests shall not exceed 15 percent. The actual required number of identical test specimens may be larger, depending on the actual coefficient of variations and necessary adjustments discussed in Section 3.4.3.

4.2 Tests for Determining Mechanical Properties:

4.2.1 Flat-rolled Carbon Steel:

4.2.1.1 The material properties, including yield point, tensile strength, elongation, area reduction and ductility of the steel used to fabricate the tested hybrid beams, shall be determined in accordance with ASTM A 370.

4.2.1.2 The base-steel thickness of the fabricated CFS structural beams shall be measured and recorded.

4.2.2 Normal-weight Concrete:

4.2.2.1 All concrete materials shall be of structural quality with values substantiated by accepted procedures, such as those referenced in IBC Section 1903.1.

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

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

4.2.2.4 Concrete test cylinders shall be cured in accordance with Section 9 of ASTM C 31 for 28 days with a five-day allowable minus tolerance. Where high-early strength cement is used, curing shall be a minimum of seven days with a two-day allowable minus tolerance. Two tests of two cylinders each shall be performed and the average compressive strength reported during a 24-hour period immediately preceding and following any full-size verification test series. Two cylinder strength results shall be averaged and constitute one test. The two tests shall be averaged (four cylinders total) to establish the compressive strength of the testing medium.

4.2.2.5 For tests conducted in high-early strength concrete, the cylinders shall be tested and the average compressive strength noted during a 12-hour period immediately preceding and following any full-scale verification test series.

4.2.2.6 For tests conducted in concrete aged 90 days or more, the compressive strength shall be the average of that for three test cylinders aged a minimum of 90 days and tested in accordance with Section 4.2.2.2.

4.2.3 Shear Connectors: The material properties, including yield and tensile strength, elongation and area reduction of the shear connectors used to fabricate the tested hybrid beams, shall be determined in accordance with ASTM A 370 as referenced in Section 7.3 of AWS D1.1.

4.3 Verification Flexural Tests (for Strength and Stiffness):

4.3.1 Configuration: Beam spans and loading shall be configured to induce all applicable limit states corresponding to flexural strength and stiffness. Beams shall be simply supported. Extremes of dimensional characteristics of CFSs (thickness, width and height) and concrete slabs (thickness and width), concrete slab at one side only or at both sides, reinforcing, CFS types, shear connector sizes and spacing, and material strength parameters shall be considered.

4.3.2 Procedure: Detailed description of test procedures shall be included in the verification test plan described in Section 4.1, which shall ensure flexural limit states (strength and stiffness). For gravity loading application, the load may be monotonically applied. The limit states shall be determined based on material properties, as determined according to Section 4.2, including strains and stresses, and the transition from uncracked to cracked concrete.

4.4 Verification Tests on Shear Connectors (for Strength and Slip):

4.4.1 Configuration: The specimens, loading and specimen support conditions shall be configured to induce shear connector related limit states with due consideration of potential loading/support eccentricity.

The configuration shall represent applications for each type of hybrid beam, including strain and stress levels, both in the shear connectors and their surrounding concrete. Extremes of dimensional characteristics of CFSs (thickness, width and height) and concrete slabs (thickness and width), concrete slab at one side only or at both sides, reinforcing, CFS types, shear connector sizes and spacing, and material strength parameters shall be considered.

4.4.2 Procedure: Detailed description of test procedures shall be included in the verification test plan described in Section 4.1, which shall ensure shear connector related limit states (strength and slip). For gravity loading applications, the load may be monotonically applied. The limit states shall be determined based on material properties, as determined according to Section 4.2, including strains and stresses in both shear connectors and surrounding concrete, and post- cracking dowel strength.

4.5 Verification Shear Tests (for Strength and Stiffness):

4.5.1 Configuration: Beam spans and loading shall be configured to induce all applicable limit states corresponding to shear strength and stiffness. Beams shall be simply supported. Extremes of dimensional characteristics of CFSs (thickness, width and height) and concrete slabs (thickness and width), concrete slab at one side only or at both sides, reinforcing, CFS types, shear connector sizes and spacing, and material strength parameters shall be considered.

4.5.2 Procedure: Detailed description of test procedures shall be included in the verification test plan described in Section 4.1, which shall ensure shear limit states (strength and stiffness). For gravity loading applications, the load may be monotonically applied. The limit states shall be determined based on material properties, as determined according to Section 4.2, including strains and stresses, and the transition from uncracked to cracked concrete.

4.6 Fire Test: The fire-resistance rating of the structural assemblies consisting of hybrid beams connected to the deck above (as illustrated in Figure 1) shall be determined in accordance with the provisions of IBC section 703 (ASTM E 119 or UL 263) or equivalent. The testing laboratory shall establish the most critical test assemblies for which recognition is sought in the ICC-ES evaluation report.

5.0 QUALITY CONTROL

5.1 The CFS portions of the hybrid beams shall be manufactured under an approved quality control program with inspections by an inspection agency accredited by the International Accreditation Service (IAS) or otherwise acceptable to ICC-ES. The inspections by the agency shall comply with Sections 1.3 and 1.4 of the ICC-ES Acceptance Criteria for Quality Documentation (AC10).

5.2 Quality documentation complying with AC10 shall be submitted for each approved fabricator.

5.3 Fabrication and assembly work requiring special inspection that is performed at an off-site facility must be done on the premises of an approved fabricator. The approved fabricator's quality assurance program for fabrication practices shall be documented and comply with the IAS Accreditation Criteria for Fabricator Inspection Programs for Reinforced Concrete (AC157) and the IAS Accreditation Criteria for Fabricator Inspection Programs for Structural Steel (AC172). In addition, the approved fabricator's quality assurance program shall address specific requirements for the hybrid beams, including, but not limited to, cold-working and CFS welding.

5.4 All installations shall be done by hybrid framing erectors approved by the applicant for the evaluation report on the hybrid beams. Special inspection shall be provided in accordance with Sections 1704.3 and 1704.4 of the IBC, with the exception that exception number 2 contained in Section 1704.3 shall not apply. Duties of the special inspector shall be included in the evaluation report.

6.0 EVALUATION REPORT RECOGNITION

The following information shall be included in the evaluation report:

6.1 Information described in Section 2.1.

6.2 The structural design method described in Sections 3.2 and 3.3.

6.3 The scope of the evaluation report as described in Sections 1.2 and 1.4.3.

6.4 Details of the fabrication program as described in Section 5.3.

6.5 Requirements that jobsite quality assurance, including special inspection, shall conform to IBC Section 1704, applicable portions of the ACI 318 and AISC 303, and Section 5.4 of this criteria.

6.6 A statement that product handling shall comply with applicable code and referenced standards, and shall be subject to the approval of the registered design professional and the code official.

6.7 Specific details of the fire-resistance-rated assemblies tested in accordance with Section 4.6, including, but not limited to, drawings showing all components and pertinent dimensions and properties. Conditions, such as the fire-resistance rating, load-bearing, nonload-bearing, restrained, unrestrained, and with or without sprayed fire-resistant materials, shall be included.

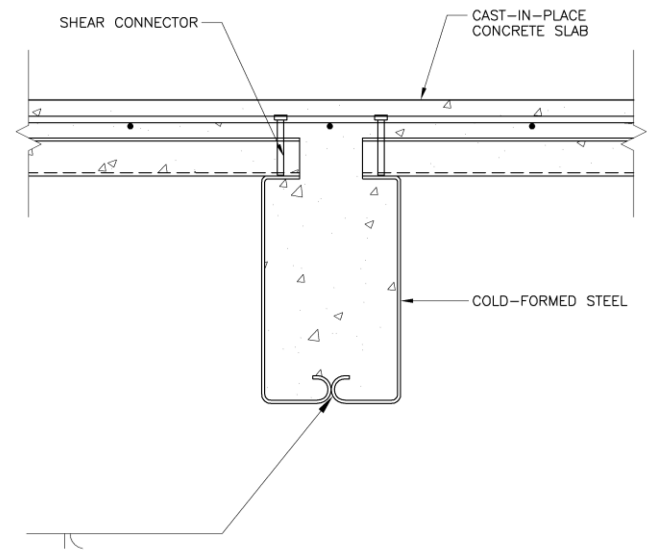
6.8 Typical details describing connections between the hybrid beams and code-compliant structural steel columns.

6.9 A statement describing the applicable design parameters for the hybrid beams that are described in Section 3.3.8.

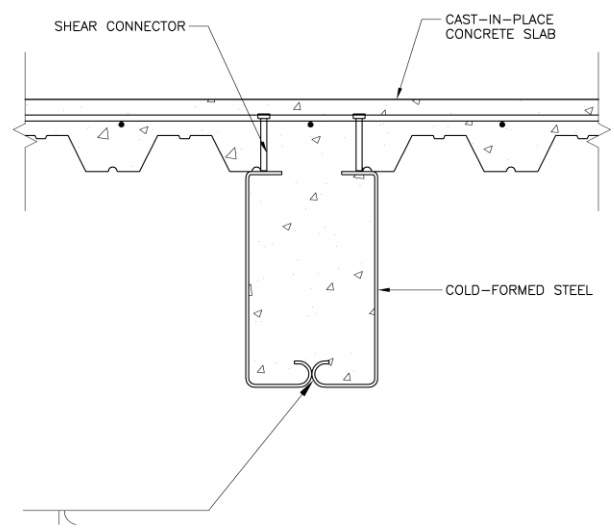
6.10 A statement that corrosion protection shall comply with the most stringent of the following: AISC 360 Chapter M and Section B.11; AISI S200 Section A4; or specific design by a registered design professional; and shall be subject to the approval of the code official.

6.11 A statement that recognition of the hybrid beams is limited to the following conditions: the hybrid beams are simply supported by code-compliant structural steel columns and support gravity loads only; and the hybrid beams consist of normal-weight concrete and CFSs with an uncoated minimum base-steel thickness greater than $^{3}/_{16}$ inch (4.76mm). ■

(a) — Steel Deck Perpendicular to Beam



(b) — Steel Deck Parallel to Beam



(c) — Concrete Slab without Metal Deck

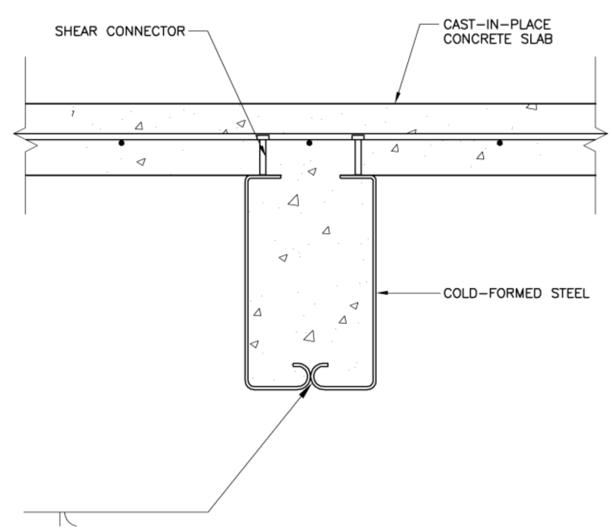


FIGURE 1—TYPICAL HYBRID BEAM CONSTRUCTION DETAIL