



**INTERNATIONAL ASSOCIATION OF PLUMBING  
AND MECHANICAL OFFICIALS, UNIFORM EVALUATION SERVICE**

**EVALUATION CRITERIA FOR  
ANCHORED STEEL FIBERS IN CONCRETE**

**EC 026 – 2018**

**(Adopted December 2018)**

**(Editorially Revised January 2019)**

**1.0 INTRODUCTION**

**1.1 Purpose:** The purpose of this evaluation criteria is to establish design requirements for anchored steel fibers in an independently reviewed evaluation report under the 2018, 2015 and 2012 *International Building Code*<sup>®</sup> (IBC) and the 2018, 2015 and 2012 *International Residential Code*<sup>®</sup> (IRC). Bases of recognition are IBC Section 104.11 and IRC Section R104.11.

**1.2 Scope:** This evaluation criteria applies to anchored steel fibers when used in structural and non-structural applications. The intended use is as an alternative or additional concrete reinforcement to materials and methods specified for reinforced concrete designed and constructed in accordance with ACI 318, SDI-C, SDI-NC or ACI 360. Evaluation of uses involving Seismic Force Resisting Systems in Seismic Design Categories D, E and F is beyond the scope of this report and shall be established by a separate evaluation criteria in accordance with Section 12.2 of ASCE 7.

**1.3 Definitions.** Where the following terms appear in this Evaluation Criteria, such terms shall have the meaning as defined in this section.

**1.3.1 Anchored Steel Fiber.** Steel fiber possessing geometric deformation at discontinuous ends, or along the length of the fiber, resulting in a positive mechanical anchorage of the fiber in the concrete matrix.

**1.3.2 Concrete Composition.** Each unique concrete mixture consisting of a specific aggregate and size, cement type and content, water and admixtures.

**1.3.3 Conventional Reinforcement.** Continuous Reinforcement other than anchored steel fibers used within the requirements of ACI 318, such as mild steel deformed bars, welded wire fabric, and prestressing steel.

**1.3.4 Design Strength.** Factored (LRFD) strength determined as the product of nominal strength and the applicable strength reduction factor.

**1.3.5 Fiber Dosage.** Weight content of fiber per unit volume of concrete.

**1.3.6 Fiber Type.** Each unique fiber characterized by specific manufacturer, type of material, and geometry.

**1.3.7 Final Product.** The final shape of the packaged anchored steel fiber.



**1.3.8 Fiber Reinforced Concrete (FRC) Matrix.** Each unique combination of fiber type, fiber dosage, concrete composition and concrete compressive strength.

**1.3.9 Flexural Strain Hardening FRC Matrix.** An FRC matrix exhibiting post-crack flexural strength exceeding that corresponding to the first-crack flexural strength of plain concrete.

**1.3.10 Flexural Strain Softening FRC Matrix.** FRC matrix that is not Flexural Strain Hardening.

**1.3.11 Half product.** Fiber drawn wire before being formed and cut into the final fiber product. Mechanical and geometric properties of the wire section of the half and the final product are identical.

**1.3.12 Pile-Supported Slab on Ground.** Non-structural slab supported on discrete supports, such as auger-cast piles, drilled piers, controlled-modulus columns, micro-piles or any other similar discrete support. Pile-supported slab on ground is isolated from the structural system and not in the load path of structural forces.

**1.3.13 Plates.** Two-dimensional elements subjected primarily to in-plane bending with or without membrane forces.

**1.3.14 Required Strength.** Member, section, or system force effects determined from the applicable analysis and the loads factored using LRFD level load combinations given by the applicable building code, or International Building Code when no applicable building code exists.

**1.3.15 Shells.** Two-dimensional elements subjected to in-plane and out-of-plane bending with or without membrane forces.

**1.3.16 Slab on Ground.** Non-structural slab continuously supported by soil strata of known stiffness modulus. Slab on ground is isolated from the structural system and not in the load path of structural forces.

**1.3.17 Structural Application.** A member or an assembly with influence on stability or strength on the overall structure. Removal of a structural application from the structure would render the structure unstable or invalidate the load path within the structure.

**1.3.18 Unreinforced Slab.** A slab on ground in which neither fibers nor conventional reinforcement is provided for resisting flexural or shear effects.

## 2.0 REFERENCED STANDARDS

**2.1 General:** Referenced standards shall be applied consistent with the provisions of the applicable edition of the IBC, as applicable, and as noted herein.

### American Concrete Institute (ACI)

ACI 224R-01	Control of Cracking in Concrete Structures
ACI 318-14	Building Code Requirements for Structural Concrete
ACI 318-11	Building Code Requirements for Structural Concrete
ACI 360R-10	Guide to Design of Slabs-on-Ground

### American Society of Civil Engineers (ASCE)

ASCE 7-10/16	Minimum Design Loads and Associated Criteria for Buildings and Other Structures
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### ASTM International

ASTM A820-16	Standard Specification for Anchored Steel Fibers for Fiber-Reinforced Concrete
ASTM C39-14a	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

ASTM C94-14	Standard Specification for Ready-Mixed Concrete
ASTM C192-07	Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory
ASTM C330-14	Standard Specification for Lightweight Aggregates for Structural Concrete
ASTM C494-13	Standard Specification for Chemical Admixtures for Concrete
ASTM C1609-12	Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)
ASTM E111-04	Standard Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus (2010)
ASTM E119-2012A	Standard Test Methods for Fire Tests of Building Construction and Materials

**Concrete Society**

TR34	Concrete industrial ground floors, a guide to design and construction (March 2016)
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**Deutscher Beton- und Bautechnik-Verein E.V.**

DBV-M	DBV-Merkblatt Industrieböden aus Stahlfaserbeton (2013)
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**European Committee for Standardization**

EN1991-1-1	Eurocode 1: Actions on structures – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings (2004)
EN14651	Test method for metallic fibre concrete. Measuring the flexural tensile strength (limit of proportionality (LOP), residual)
EN1992-1-1	Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings (2004)

**Deutscher Ausschuss für Stahlbeton (DAfStb)**

DAfStb Guideline	DAfStb Guideline “Steel Fibre Reinforced Concrete (2012) Commentary on the DAfStb Guidelines “Steel Fibre Reinforced Concrete” (2012)
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**IAPMO Uniform ES**

EC 007	Evaluation Criteria for Steel Composite, Non-Composite and Roof Deck Construction
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**International Code Council**

2018, 2015 and 2012 IBC	International Building Code®
2018, 2015 and 2012 IRC	International Residential Code®

**International Organization for Standardization**

ISO/IEC 17011:2004	Conformity Assessment--General Requirements for Accreditation Bodies Accrediting Conformity Assessment Bodies
ISO/IEC 17025:2005	General Requirements for the Competence of Testing and Calibration Laboratories

**Federation international du beton (fib)**

fib MC2010	fib Model Code for Concrete Structures (2010)
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**SFRC Consortium**

SFRC Guideline	Design Guideline for Structural Applications of Steel Fibre Reinforced Concrete (2014)
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**Steel Deck Institute**

ANSI/SDI C-2010/2017	Design Standard for Composite Steel Floor Deck Slabs
ANSI/SDI NC-2010/2017	Design Standard for Non-Composite Steel Floor Decks

**Swedish Standard Institute**

SS 812310:2014

Fibre Concrete – Design of Fibre Concrete Structures (2014)

**Underwriters Laboratories**

UL 263-11

Standard for Fire Tests of Building Construction and Materials

**3.0 BASIC INFORMATION**

- 3.1 General:** The requirements of this section shall be considered in the evaluation of the anchored steel fibers.
- 3.2 Product Description:** The following information on the anchored steel fibers, as defined by Section 1.3.1 of this criteria, shall be submitted for inclusion in the evaluation report.
- Product Commercial Designation:** full product brand name as indicated on the packaging along with, when applicable, any corresponding explanation of the type and the properties indicated by the commercial designation.
  - Raw Material Tensile Strength:** The tensile strength for raw material shall be submitted based on certification or mill tests supplied by the manufacturer. The raw material tensile strength shall be evaluated either based on the final product or the half product.
  - Applicable Product Standard:** The anchored steel fiber shall be randomly sampled and verified as compliant with ASTM A820.
  - Description of Shape:** The cross-sectional shape shall be described, and it shall consist of a qualitative and dimensional description of a round wire shape with end-fiber deformations.
  - Elongation:** Elongation or strain shall be reported when stipulated by the referenced standard.
- 3.3 Fire Resistance:** At least one roof and one floor concrete assembly designed to be reinforced with anchored steel fibers, alone or in combination with conventional reinforcement, as applicable, shall be tested for fire resistance in accordance with ASTM E119 or UL 263. Full-scale fire resistance testing specific to the application is not required where an accompanying engineering study prepared by a testing laboratory establishes the equivalency of the fibers to tests on an assembly with conventional reinforcement in terms of fire resistance.
- 3.4 Installation Instructions:** The installation procedures shall be submitted and stated as a requirement in the evaluation report. For all tests under this evaluation criteria, the manufacturer shall provide the evaluation service agency and the laboratories conducting the testing a copy of its installation instructions. All test specimens shall be prepared in accordance with installation instructions and procedures used in the field.
- 3.5 Packaging and Identification:** Method(s) of packaging and product identification shall be included in the evaluation report. Identification shall include the manufacturer's name and address, product name, and the evaluation service agency's evaluation report number or mark of conformity.
- 3.6 Testing Laboratories:** Where test data is provided in support of the evaluation report, or where initial qualifying product data is required by an evaluation service agency, testing laboratories shall be accredited for the applicable testing procedures in accordance with ISO/IEC 17025 by a recognized accreditation body conforming to ISO/IEC 17011. Testing at a non-accredited laboratory shall be permitted by the evaluation service agency, provided the testing is conducted under the supervision of an accredited laboratory and the supervising laboratory issues the test report.
- 3.7 Test Reports:** Test reports shall comply with Annex A of this criteria. The test reports used in the conjunction with the requirements of an evaluation report generated using these criteria, but whose data is not contained in the body of the report, shall comply with the same requirements as the test report whose data is used in the development of the evaluations report, along with any specific requirements stipulated in the evaluation report.
- 3.8 Product Sampling:** Sampling of fibers for tests under this criteria shall comply with Annex A of this criteria.

#### **4.0 ORGANIZATION OF THE EVALUATION REPORT**

- 4.1** The evaluation report shall identify the specific uses, applications and limit states for which anchored steel fibers may be used as a full or partial alternative, or an addition, to conventional reinforcement. These uses, applications, and limit states shall be within the scope of the provisions of the code (IBC, IRC, ACI 318, ACI 360) for which the anchored steel fibers are intended to act as concrete reinforcement. Specific sections of ACI 318 for which the alternative use is proposed, shall be identified in the evaluations report.
- 4.2** With respect to ACI 318, the proposed alternative uses shall identify any limitations or conditions of the alternative use along with the corresponding computational model defining the alternative structural usage.
- 4.3** With respect to ACI 318, the report shall include a statement indicating that the alternative uses not explicitly identified by the evaluations report shall be considered as not permitted.
- 4.4** With respect to ACI 360, the evaluation report shall provide the criteria for the design of non-structural members and systems consistent with the overall margin of safety between the required and the design member or system strength as required by ACI 360. In lieu of ACI 360, the calibration of margin of safety between the required and design strengths shall be permitted to be performed using the criteria provided by TR34 or DBV-M.
- 4.5** With respect to SDI-C, diaphragm capacity of composite slabs shall be evaluated in accordance with EC 007 with accurate documentation of the concrete mix design and FRC matrix applicable to each vertical load and lateral load (diaphragm) configuration. Evaluation reports developed on the basis of this criteria may be used for anchored steel fiber dosage-based interpolation of mechanical properties used for the purposes of determination of nominal strength. For flexural strength of composite slabs, the design criteria developed for steel FRC plain slabs may be used. Where the flexural strength of the composite slabs intends to capture the effect of the deck, the composite slab strength shall be computed in accordance with SDI-C where the flexural strength provided by the anchored steel fibers is determined using the methods of evaluations developed in the basis of this criteria for purposes indicated in Section 4.1 of this criteria.
- 4.6** For applications involving diaphragm capacities or flexural strength of non-composite slabs whose design is governed by the auspices of SDI-NC, the methodology developed for the purposes indicated by Section 4.1 of these criteria may be used.
- 4.7** The evaluation report shall provide the requirements for required forces, system ductility, definition and determination of mechanical properties, and criteria for determining the available strength of members. When applicable, the determination of required forces shall consider member or system stability by accounting for geometric non-linearity.

#### **5.0 MECHANICAL PROPERTIES**

- 5.1** The mechanical properties of the steel FRC shall be established through testing in a laboratory complying with the requirements of ISO/IEC 17025 or another laboratory approved by the building official having jurisdiction.
- 5.2** The test standard stipulated by the evaluation report shall be consistent and commensurate with the design criteria presented in the report. No alternative test standard shall be used for the design method presented in the evaluation report unless it can be demonstrated that such a test standard yields the mechanical properties compactible with and calibrated to the proposed design method. The pertinent material mechanical properties and the associated parameters such as stress conversion relationships and interpolation ranges, shall consistent with the selected referenced standard. Evaluation criteria for such an analysis shall be established to the satisfaction of the evaluation service agency.

- 5.3** It shall be permitted to develop design methods using the properties from the following test standards: ASTM C1609, EN14651, and DAFStb Guideline Annex 0. The design methods contained in the evaluation reports shall utilize the same designations for the nominal material properties as in the applicable test standards.
- 5.4** When applicable, the evaluation report shall provide the criteria for the conversion of the mechanical properties to design properties. Specifically, when the design methods described in the evaluation report utilize axial tensile strength of the FRC matrix, but the test standards mandate the reporting of residual flexural stress values, the evaluation report shall define the method of conversion.
- 5.5** The evaluation report shall establish requirement whereby each specific design property is unique to a specific FRC matrix. Evaluation report shall only permit the interpolation of properties relative to dosage. The interpolation range shall be defined by the evaluation report such that the no statistical bias or statistical uncertainty materially affects the reliability of the proposed design requirements.
- 5.6** The evaluation report shall provide the criteria for the minimum number of replicate tests upon which a nominal mechanical property may be established as well as the limiting statistical indices rendering the derived property acceptable. The minimum number of tests and the corresponding maximum acceptable coefficient of variation shall be shown as consistent with the reliability index upon which the design criteria is established. However, a minimum of six replicate tests with the corresponding maximum coefficient of variation of 0.25 shall apply for each unique FRC matrix, unless an appropriate adjustment is made to the indices used to remove the statistical bias.

## **6.0 DEVELOPMENT OF DESIGN METHOD and SAFETY CONCEPT**

- 6.1** For structural applications, the proposed design criteria shall be constructed to possess the reliability index equivalent to that resulting by the corresponding ACI 318 provision. Such an evaluation may be based on through component, section, or system specific testing, defined through a separate evaluation criteria. The reliability analysis, also to be defined by this separate evaluation criteria, shall at the minimum consider the IBC load combinations, statistical properties of all constitutive mechanical properties, including FRC, and be based on the first-order second-moment reliability analysis. Higher orders of reliability analysis shall be permitted. However, the resulting strength reduction factors shall not exceed those values provided by Chapter 9 of ACI 318-11, or Chapter 21 of ACI 318-14, as applicable.
- 6.2** The requirements stated in Section 6.1 of this criteria are also permitted to be established using existing provisions of another consensus standard, provided the standard stipulates the reliability basis is equal to at least that required by the corresponding ACI 318 provision. When criteria is adopted from another standard on this basis, the calibration shall occur, assuring that at least the identical overall margin of safety is obtained between the available and the required forces over the applicable range of loading conditions and applications when using strength level load combinations of IBC.
- 6.2.1** It is permissible to use EN1991-1-1 in conjunction with either the combination of DIN EN1992-1-1 and DAFStb Guideline, or EN1992-1-1 and SFRC Guideline, SS 812310, or fib Model Code to establish the requirements of this Section on the basis of overall margin of safety without further verification of equivalent reliability, provided justification is submitted.
- 6.3** For non-structural provisions, it shall be acceptable to reduce the load factors, increase resistance factors, or linearly scale nominal values of resistances as appropriate to achieve the overall safety margin as indicated by Section 4.4 of this criteria.
- 6.4** Serviceability criteria shall be based on nominal properties of the FRC material. The serviceability criteria pertaining to minimum shrinkage and temperature reinforcement shall be based on the provision of nominal tensile strength equivalent to that of the conventional reinforcement. The evaluation report shall provide criteria for crack control, deflections, and minimum reinforcement under service load.

- 6.5** Statistical analysis leading to the required reliability indices, such as strength reduction factors, shall comply with the requirements of Section 5.6 of this criteria. Where the calibration occurs in accordance with Section 6.2 of this criteria, it shall be permissible to calculate the resistance factors as provided by that section, provided that the FRC properties are based on a minimum of six replicate tests and a maximum coefficient of variation of 0.25.

## **7.0 APPLICATIONS**

- 7.1** The evaluation report developed based on these criteria shall define applications and distinguish between structural and non-structural uses and their respective requirements.
- 7.2** Structural applications shall contain description of specific applicable limit states commensurate with ACI 318 with the statement of ACI 318 Sections and provisions for which an alternative is provided through the use of steel FRC.
- 7.3** The evaluation report shall include requirements precluding the usage of anchored steel fiber reinforcement as the method of providing structural integrity against progressive collapse.
- 7.4** Where the stability of a structural system or a member is provided through anchored steel fiber reinforcement, other requirements notwithstanding, the Evaluation Report shall be structured such that only steel FRC matrix capable of providing strain hardening response for the action providing stability to the system. Strain-softening response shall be permitted in non-structural applications. In lieu of a strain hardening FRC matrix, where strain hardening response is required, it shall be permitted to achieve strain hardening through the combination of a strain softening FRC matrix and conventional continuous reinforcement.
- 7.5** Requirements pertaining to non-structural applications need not include reinforcement for structural integrity.
- 7.6** When fire resistance is included in the scope of the Evaluation Report, information in accordance with Section 3.3 of this criteria shall be provided.

## **8.0 CONSTRUCTION QUALITY ASSURANCE FOR FRC**

- 8.1** The evaluation report shall provide requirements for quality control. The quality control requirements shall be constructed as consistent with the design properties and the reliability provided by the design procedures.
- 8.2** When the design criteria are established by the process of calibration with an existing consensus standard, the quality assurance requirements shall be those stipulated by the standard.
- 8.3** The quality control requirements shall at the minimum stipulate the following:
- 8.3.1** Statement of mix design for each unique FRC matrix
  - 8.3.2** Statement of the minimum number of replicate tests establishing the mechanical properties of each specific FRC matrix
  - 8.3.3** Method and frequency of verification of in-situ dosage and the corresponding tolerance
  - 8.3.4** Verification of labeling requirements set forth in Section 3.5 of this criteria.
  - 8.3.5** Minimum and maximum applicable dosage limits or mechanical properties permissible for each particular fiber type.

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**9.0 QUALITY ASSURANCE – MANUFACTURING OF ANCHORED STEEL FIBERS:**

- 9.1** Quality documentation complying with the IAPMO UES Minimum Requirements for Listee’s Quality Assurance System (ES-010) or equivalent shall be submitted.
- 9.2** A qualifying inspection shall be conducted at each manufacturing facility by an approved inspection agency. The approved inspection agency shall be accredited in accordance with ISO/IEC 17020 by a recognized accreditation body conforming to ISO/IEC 17011.
- 9.3** An annual inspection shall be conducted at each manufacturing facility by an approved inspection agency. The approved inspection agency shall be accredited in accordance with ISO/IEC 17020 by a recognized accreditation body conforming to ISO/IEC 17011.

**10.0 EVALUATION REPORT RECOGNITION**

- 10.1 General:** The Evaluation Report shall include the following:
- 10.2** Basic information required by Section 3.0 of this criteria including product description, packaging and identification.
- 10.3** Description of limit states, methods of analysis and applications covered by the Evaluation Report along with corresponding criteria.
- 10.4** Scope and limitation of each design criteria.
- 10.5** Cross-reference to specific sections of ACI 318, or another appropriate standard for which the Evaluations Report provides alternative criteria.
- 10.6** Description of each application and its classification as structural or non-structural.
- 10.7** Detailed description of quality assurance procedures and methods.
- 10.8** Description of methods for establishing the required member, system or section forces
- 10.9** Description of fire-resistance ratings, as applicable.
- 10.10** Use of FRC in Seismic Force Resisting Systems in Seismic Design Categories C, D, E, or F is beyond the scope this report.



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**Annex A**  
**Test Report Content**

- 1.0** The services performed by the testing laboratory shall be documented by a retrievable report that accurately, clearly, objectively, and unambiguously presents measurements, observations, examinations, and test results in accordance with the reporting requirements of test method(s). Each test or inspection report also shall include the following unless the code, evaluation criteria, or the test standard requirements specify otherwise:
- 1.1** A title, for example, “Report on EN114651 Beam Tests using 5D fibers;”
  - 1.2** The name, address, and contact information of the laboratory.
  - 1.3** A unique identification of the report (such as report number), the issue date, a sequential number for each page, and the total number of pages.
  - 1.4** The name and address of client.
  - 1.5** Description of, condition of, and clear identification of the item tested.
  - 1.6** Date test(s) were conducted.
  - 1.7** Identification of test standards or description of any non-standard methods used.
  - 1.8** Any deviations from, additions to, or exclusions from, the test standard and any other information relevant to the specific test, such as environmental conditions;
  - 1.9** Measurements, observations, examinations, and test results, supported by tables, graphs, sketches, and photographs, as appropriate, including a description of the failure mode or condition of item at conclusion of the tests;
  - 1.10** Conclusions or summary statements, including, when applicable, a statement indicating whether the product passed or failed the test;
  - 1.11** A statement the results apply only to the items tested;
  - 1.12** A statement that the report shall not be reproduced, except in full, without the prior written approval of the laboratory; and
  - 1.13** Name(s) of individual(s) performing the tests;
  - 1.14** A signature and title, or an equivalent identification, of the person(s) accepting responsibility for the content of the report on behalf of the laboratory.
  - 1.15** Identification of results obtained from tests subcontracted by the laboratory to others. The laboratory shall not represent the services of others as its own.
  - 1.16** Indication of the laboratory compliance with the requirements of ISO/IEC 17025:2005.
- 2.0** In addition to the requirements of Sections 1.0, 2.0 and 3.0 of this Annex, each test report, where necessary for the proper interpretation or understanding of the report, shall include the following:
- 2.1** When applicable, project title and reference designation.
  - 2.2** Reference to relevant code, evaluation criteria, or other requirement(s).

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- 2.3** A statement indicating compliance with relevant code, evaluation criteria, or other requirement(s).
- 2.4** Other reporting requirements of the evaluation agency, the client, or relevant authority.
- 3.0** In addition to the requirements of Sections 1.0, 2.0, 3.0 and 4.0 of Annex A, test reports presenting results shall include the following with respect to sampling:
- 3.1** Date of sampling or date sample received, as appropriate.
- 3.2** Clear identification of the material sampled including manufacturer, brand name, lot number, source, or similar unique information, as applicable.
- 3.3** Sampling location, where relevant, using an explicit description, diagram, sketch, or photograph, as applicable.
- 3.4** Identification of sampling methods used, or sampling plan or procedure if a non-standard method is used.
- 3.5** Deviations from, additions to, or exclusions from standard sampling methods or predetermined sampling plans or procedures.
- 3.6** Details of environmental conditions present during the sampling such as rain or freezing weather that may have affected the testing of the sample or the interpretation of the test results.
- 3.7** If assemblies are tested (structural assemblies, fire-rated assemblies, etc.), identification of the assemblies, preferably with illustrations. The report shall identify the parties constructing the assemblies and shall also address witnessing and/or verifying the construction.
- 4.0** When interpretations of tests are included in the report, the basis for the interpretations shall be clearly explained. Interpretations commonly include determination of compliance or noncompliance of the results with requirements of the test method or evaluation criteria.
- 5.0** Material revisions or additions to a report after initial issue shall be made in a further document clearly indicating the revised information and clearly referencing the original report identification. Such revisions or additions shall meet the relevant requirements of Section 2.0.
- 6.0** Transmission of test reports by electronic means shall follow documented procedures to ensure compliance with the requirements of this evaluation criteria, and that confidentiality is preserved.