ICC EVALUATION SERVICE®

ICC Evaluation Service, LLC
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November 22, 2024

TO: **PARTIES INTERESTED IN FIBER-REINFORCED POLYMER (FRP) BARS FOR INTERNAL REINFORCEMENT OF CONCRETE MEMBERS**

SUBJECT: Proposed Revisions to the Acceptance Criteria for Fiber-reinforced Polymer (FRP) Bars for Internal Reinforcement of Concrete Members, Subject AC454-0225-R1 (YM/MC)

Hearing Information:
WebEx Event Meeting
Wednesday, February 19, 2025
8:00 am Pacific Standard Time
Click the date above to register

Dear Colleague:

You are invited to comment on proposed revisions to ICC-ES Acceptance Criteria for Fiber-Reinforced Polymer (FRP) Bars for Internal Reinforcement of Concrete Members (AC454), which will be discussed at the Evaluation Committee hearing noted above. The criteria is being revised to expand the scope in Section 1.2 and allow the use of FRP bars as internal reinforcement of concrete members in Types I, II, III or IV construction based on item 20 of IBC Section 603.1 and as indicated in the enclosed letter from the proponent, Basalt Engineering, LLC, dated October 25, 2024.

The following changes to AC454 to reflect the expanded scope can be summarized as follows:

1. Section 4.8 of AC454 has been revised by removing noncombustibility test requirements.
2. Section 7.4 for Evaluation Report Requirements of AC454 has been revised to allow usage when non-fire resistance rated construction is permitted by the IBC.
3. Section 7.8 for Evaluation Report Requirements of AC454 has been added to allow for construction types.

Should the committee approve the proposed revisions to the criteria, the ICC-ES staff will not recommend a mandatory compliance date. Compliance with the revised criteria will therefore be at the option of existing report holders. However, it should be noted that current applicants for new reports will be required to address any changes that are approved by the committee.

You are invited to submit written comments on this or any other agenda item, or to attend the Evaluation Committee hearing and present your views in person. If you wish to contribute to the discussion, please note the following:

1. Regarding written comments and presentations:

   a. You should submit these via e-mail to es@icc-es.org by the applicable due date.

   b. Comments are to be received by **December 18, 2024.** These written comments will be forwarded to the committee before the meeting, and will also be posted on the ICC-ES web site shortly after the deadline for submission. Written comments that are not submitted by this deadline will not be considered at the meeting.

   c. Rebuttal comments, from the proponent noted in this letter, are to be received by **January 9, 2025**. They will be forwarded to the committee before the meeting, and will also be posted on the ICC-ES web site shortly after the deadline for submission. Written rebuttal comments that are not submitted by the deadline will not be considered at the meeting.

   d. If you want to make a visual presentation at the hearing, it must be received in PowerPoint format. The presentation is to be received by **January 24, 2025.** These will be forwarded to the committee before the meeting, and will also be posted on the ICC-ES web site after the deadline for submission. Presentations that are not submitted by the deadline cannot be presented at the meeting. **Note:** Videos will not be posted on the web site.

      Presentations will be retained with other records of the meeting.

   e. ICC-ES will post to the web site, on **February 5, 2025**, memos by the ICC-ES staff, responding to the previously received public comments.

   f. If you miss the deadlines for submission of written comments and visual presentations, your verbal comments can be presented at the meeting.

   g. Proposed criteria, written public comments, visual presentations, and responses by ICC-ES staff for this agenda item are all available on our website.

2. Regarding verbal comments and presentations:

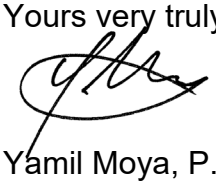
   Please plan to speak for not more than ten minutes. As noted above, visuals are to be in PowerPoint format.

3. Keep in mind that all materials submitted for committee consideration are part of the public record and will not be treated as confidential. It is the presenter's responsibility to certify to ICC-ES staff that no materials infringe copyright.

4. Please do not communicate with committee members before the meeting about any items on the agenda.

We appreciate your interest in the work of the Evaluation Committee. If you have any questions, please contact me at (800) 423-6587, extension 3691, or Manuel Chan, S.E., Principal Structural Engineer, at extension 3288. You may also reach us by e-mail at es@icc-es.org.

Yours very truly,



Yamil Moya, P.E.
Senior Staff Engineer

YM/ls

Encl.

cc: Evaluation Committee

BASALT ENGINEERING

Date: October 25, 2024

To: ICC Evaluation Service, LLC

Western Regional Office

3060 Saturn Street, Suite 100

Brea, CA 92821

Subject: Proposal for Revisions to AC454 Regarding the Use of Bars in Types I, II, III and IV Construction

Dear Mr. Chan,

I hope this letter finds you well. Following our recent discussions and in light of the ICC-ES resolution concerning the use of Fiber Reinforced Polymer (FRP) bars in applications in Types I, II, III or IV construction, I am writing to formally propose revisions to AC454 for consideration at the upcoming hearing on February 19, 2025.

Proposed Changes to AC454:

1. **Inclusion of FRP Bars in Types I, II, III, IV or V Construction:** We propose adding to the scope statement in Section 1.2 that FRP bars used in reinforced concrete elements complying with ACI 440.11 may be utilized in Types I, II, III, IV or V construction as defined in IBC Chapter 6. Compliance with Section 4.8 is required where evaluation of fire-resistance-rated construction is sought.
2. **Revision of Fire-Resistance Testing Requirements:** In Section 4.8, we suggest removing the requirement for non-combustibility tests for constructions in other than Type V and making fire-resistance-rated construction tests optional.
3. **Specificity in Fire-Resistance-Rated Construction:** In Section 7.4, we recommend revising the statement to specifically address fire-resistance-rated construction.
4. **New Section on FRP Bars:** We propose a new Section 7.8 allowing the use of FRP bars in Types I, II, III, IV or V construction.

Rationale for Revisions to Allow FRP Bars in Types I, II, III or IV construction:

- **FRP Bars are Always Embedded and Encapsulated:** FRP bars are inherently protected by the surrounding concrete, which provides substantial fire resistance. The minimum concrete cover effectively mitigates fire exposure and risks associated with the combustibility of the resin used in FRP bars.

- **Guidance from ACI 440.11-22:** Design of FRP reinforced concrete members must follow ACI 440.11-22, which requires adequate concrete cover for various structural elements.
- **IBC Compliance for Use of Combustibles Materials in Types I and II Construction:** Section 603 of the IBC permits the use of combustible materials in Types I and II construction. Item 20 of IBC Section 603.1 allows combustible aggregates, component materials and admixtures in concrete. Since the FRP bars are fully encapsulated in concrete, our opinion is that this code allowance can be extended to FRP bars used in reinforced concrete. This further aligns with the intent of the code to mitigate fire spread risks.

Next Steps:

We appreciate the open process of the ICC-ES Acceptance Criteria hearing and acknowledge our role as proponents in providing support for our proposal. We believe that these revisions will enhance the understanding and acceptance of FRP bars in relevant construction applications.

Please find attached the initial changes to AC454 for your review.

Thank you for considering our proposal. We look forward to your feedback and to further discussions.

Sincerely,

Tony Lahnston
Director
tony@basalt-usa.com

978-886-4791
Basalt Engineering LLC

ICC EVALUATION SERVICE, LLC, RULES OF PROCEDURE FOR THE EVALUATION COMMITTEE

1.0 PURPOSE

The purpose of the Evaluation Committee is to review and approve acceptance criteria on which evaluation reports may be based.

2.0 MEMBERSHIP

2.1 The Evaluation Committee has a membership of not fewer than nine, with one of the members named by the ICC-ES president each year to serve as the chairperson–moderator.

2.2 All members of the committee shall be representatives of a body enforcing regulations related to the built environment.

2.3 Persons are appointed to the committee by the ICC-ES president, from among individuals who have formally applied for membership.

2.4 The ICC-ES Board of Managers, using simple majority vote, shall ratify the nominations of the president.

2.5 Committee membership is for one year, coinciding with the calendar year. Members may be renominated and reappointed.

2.6 In the event that a member is unable to attend a committee meeting or complete a term on the committee, the ICC-ES president may appoint a replacement to fill in at the meeting or for the remainder of the member's term. Any replacement appointed for only one meeting must have prior experience as a member of the Evaluation Committee. Appointments under this section (Section 2.6) are subject to ratification as noted in Section 2.4.

3.0 MEETINGS

3.1 The Evaluation Committee shall schedule meetings that are open to the public in discharging its duties under Section 1.0, subject to Section 3.0.

3.2 All scheduled meetings shall be publicly announced. There shall be three to six meetings per year (as necessary).

3.3 More than half of the Evaluation Committee members, counting the chairperson, shall constitute a quorum. A majority vote of members present is required on any action. To avoid any tie vote, the chairperson may choose to exercise or not exercise, as necessary, their right to vote.

3.4 In the absence of the chairperson–moderator, Evaluation Committee members present shall elect an alternate chairperson from the committee for that meeting. The alternate chairperson shall be counted as a voting committee member for purposes of maintaining a committee quorum and to cast a tie-breaking vote of the committee.

3.5 Minutes shall be kept and shall be the official record of each meeting.

3.6 An electronic record of meetings may be made by ICC-ES if deemed necessary; no other audio, video, electronic recordings of the meetings will be permitted. Visual aids (including, but not limited to, charts, slides, videos, or presentation software) viewed at meetings shall be permitted only if the presenter provides ICC-ES before the presentation with a copy of the visual aid in a medium which can be retained by ICC-ES with its record of the meeting and which can also be provided to interested parties requesting a copy.

3.7 Parties interested in the deliberations of the committee should refrain from communicating, whether in writing or verbally, with committee members regarding agenda items. All written communications and submissions regarding agenda items must be delivered to ICC-ES and shall be considered nonconfidential and available for discussion in open session of an Evaluation Committee meeting. Such materials will be posted on the ICC-ES web site (www.icc-es.org) prior to the meeting. Comments and submissions not meeting the following deadlines will not be considered at the meeting:

- Initial comments on agenda items shall be submitted at least 28 days before the scheduled meeting.
- A rebuttal comment period shall follow, whereby rebuttal comments to the initial comments may be submitted by the proponent at least 21 days before the scheduled meeting.
- Those planning on giving a visual presentation at the meeting must submit their presentation, in PowerPoint format only, at least 10 days before the scheduled meeting.

The committee reserves the right to refuse recognition of communications which do not comply with the provisions of this section.

4.0 CLOSED SESSIONS

Evaluation Committee meetings shall be open except that at the discretion of the chairperson, staff counsel may be necessary. Also, matters related to clients or potential clients covered by confidentiality requirements of ICC-ES Rules of Procedure for Evaluation Reports are discussed only during closed meetings.

5.0 ACCEPTANCE CRITERIA

5.1 Acceptance criteria are established by the committee to provide a basis for issuing ICC-ES evaluation reports on products and systems under codes referenced in Section 2.0 of the Rules of Procedure for Evaluation Reports. They also clarify conditions of acceptance for products and systems specifically regulated by the codes.

Acceptance criteria may involve a product, material, or method of construction. Consideration of any acceptance criteria must be in conjunction with a current and valid application for an ICC-ES evaluation report, an existing ICC-ES evaluation report, or as otherwise determined by the ICC-ES President.

EXCEPTIONS: The following acceptance criteria are controlled by the ICC-ES executive staff and are not subject to committee approval:

- The Acceptance Criteria for Quality Documentation (AC10)
- The Acceptance Criteria for Test Reports (AC85)
- The Acceptance Criteria for Inspections and Inspection Agencies (AC304)

5.2 Procedure:

5.2.1 Proposed acceptance criteria shall be developed by the ICC-ES staff and discussed in open session with the Evaluation Committee during a scheduled meeting, except as permitted in Section 4.0 of these rules.

5.2.2 Proposed acceptance criteria shall be available to interested parties at least 30 days before discussion at the committee meeting.

5.2.3 The committee shall be informed of all pertinent written communications received by ICC-ES.

5.2.4 Attendees at Evaluation Committee meetings shall have the opportunity to speak on acceptance criteria listed on the meeting agenda, to provide information to committee members. In the interest of fairness, each speaker requesting to testify on a proposed acceptance criteria or proposed changes to an existing acceptance criteria will be given the same amount of time, as follows:

a. A 10-minute time limit applies to speakers giving their first testimony on any item, which applies to both verbal testimony and/or visual presentations.

b. A 5-minute time limit applies to speakers returning to the microphone to offer additional testimony and/or to rebut testimony given by others.

c. A 2-minute time limit applies to speakers offering testimony on the staff recommendation to criteria.

Should a company have multiple speakers, the speaker time limits above apply the company, in that multiple speakers from the same company shall share the testimony time, i.e., multiple speakers from the same company shall not each get their own testimony times. Time limits do not include time needed to answer questions from the staff and/or committee members. The chairperson–moderator shall have limited authority to modify time limitations on testimony. The chairperson–moderator shall also have the authority to adjust time limits as necessary in order to get through the hearing agenda.

An automatic timing device shall keep time for testimony and shall provide the time remaining to the speaker testifying. Interruptions during testimony will not be tolerated. It is the responsibility of the chairperson–moderator to maintain decorum and order during all testimony.

5.3 Approval of any action on an acceptance criteria shall be as specified in Section 3.3 of these rules. Possible actions made by the Evaluation Committee include: Approval; Approval with Revisions; Disapproval; or Further Study. The Evaluation Committee must give the reason(s) for any Disapproval or Further Study actions with specific recommendations.

5.4 Actions of the Evaluation Committee may be appealed in accordance with the ICC-ES Rules of Procedure for Appeal of Acceptance Criteria or the ICC-ES Rules of Procedure for Appeals of Evaluation Committee Technical Decisions.

6.0 COMMITTEE BALLOTING FOR ACCEPTANCE CRITERIA

6.1 Acceptance criteria may be revised without a public hearing following a 30-day public comment period and a majority vote for approval by the Evaluation Committee (i.e., alternative criteria development process), when at the discretion of the ICC-ES executive staff, the subject is a revision that requires formal action by the Evaluation Committee.

6.2 Negative votes must be based upon one or more of the following, for the ballots to be considered valid and require resolution:

a. *Lack of clarity*: There is insufficient explanation of the scope of the acceptance criteria or insufficient description of the intended use of the product or system; or the acceptance criteria is so unclear as to be unacceptable. (The areas where greater clarity is required must be specifically identified.)

b. *Insufficiency*: The criteria is insufficient for proper evaluation of the product or system. (The provisions of the criteria that are in question must be specifically identified.)

c. *The subject of the acceptance criteria is not within the scope of the applicable codes*: A report issued by ICC-ES is intended to provide a basis for approval under the codes. If the subject of the acceptance criteria is not regulated by the codes, there is no basis for issuing a report, or a criteria. (Specifics must be provided concerning the inapplicability of the code.)

d. *The subject of the acceptance criteria needs to be discussed in public hearings*. The committee member requests additional input from other committee members, staff or industry.

6.3 An Evaluation Committee member, in voting on an acceptance criteria, may only cast the following ballots:

- Approved
- Approved with Comments
- Negative: Do Not Proceed

7.0 COMMITTEE COMMUNICATION

Direct communication between committee members, and between committee members and an applicant or concerned party, with regard to the processing of a particular acceptance criteria or evaluation report, shall take place only in a public hearing of the Evaluation Committee. Accordingly:

7.1 Committee members receiving an electronic ballot should respond only to the sender (ICC-ES staff). Committee members who wish to discuss a particular

matter with other committee members, before reaching a decision, should ballot accordingly and bring the matter to the attention of ICC-ES staff, so the issue can be placed on the agenda of a future committee meeting.

7.2 Committee members who are contacted by an applicant or concerned party on a particular matter that will be brought to the committee will refrain from private communication and will encourage the applicant or concerned party to forward their concerns through the ICC-ES staff in writing, and/or make their concerns known by addressing the committee at a public hearing, so that their concerns can receive the attention of all committee members.■

Revised May 2024

ICC EVALUATION SERVICE®

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PROPOSED REVISIONS TO THE ACCEPTANCE CRITERIA FOR FIBER–REINFORCED POLYMER (FRP) BARS FOR INTERNAL REINFORCEMENT OF CONCRETE MEMBERS

AC454

Proposed November 2024

PREFACE

Evaluation reports issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the International family of codes, and may include other codes, as applicable.

For alternative materials, design and methods of construction and equipment, see Section 104.2.3 of the 2024 *International Building Code*® (IBC), Section R104.2.2 of the 2024 *International Residential Code*® (IRC), Section 104.11 of the 2021 IBC and earlier editions, and Section R104.11 of the 2021 IRC and earlier editions.

ICC-ES may consider alternate criteria for report approval, provided the report applicant submits 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. ICC-ES retains the right to refuse to issue or renew any evaluation report, if the applicable product, material, 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 injury or unreasonable damage.

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

PROPOSED REVISIONS TO THE ACCEPTANCE CRITERIA FOR FIBER–REINFORCED POLYMER (FRP) BARS FOR INTERNAL REINFORCEMENT OF CONCRETE MEMBERS (AC454)

1.0 INTRODUCTION

1.1 Purpose: The purpose of this acceptance criteria is to establish requirements for glass or basalt fiber–reinforced polymer (FRP) bars to be evaluated in an ICC Evaluation Service, LLC (ICC-ES), evaluation report under the 2021, 2018, 2015, 2012 and 2009 *International Building Code*® (IBC) and the 2021, 2018, 2015, 2012 and 2009 *International Residential Code*® (IRC). Bases of evaluation are IBC Section 104.11 and IRC Section R104.11.

The reason for the development of this criteria is to provide guidelines for the evaluation of an alternative reinforcement for steel-reinforced concrete structures, where the codes do not provide design provisions, or requirements for testing and determination of physical and mechanical properties of this type of reinforcement products.

1.2 Scope: This acceptance criteria applies to glass fiber-reinforced polymer (GFRP) or basalt fiber-reinforced polymer (BFRP) bars, in cut lengths, bent shapes and continuous closed stirrups and ties (hoops), that are used to reinforce concrete structural members. Items evaluated include material properties; performance under accelerated environmental exposures; performance under exposure to fire conditions; and structural design procedures. This criteria is applicable to FRP bars that are solid and have circular cross sections, or solid but have a cross sections other than circular, or hollow and have circular cross sections. FRP bars under this criteria are used as flexural reinforcement in structural concrete members such as beams, shallow foundations and one-way or two-way slabs, and as shear reinforcement for flexural members. This criteria also applies to FRP bars that are solid and have circular cross section, and are used as longitudinal reinforcement in columns or walls. Application of FRP bars under this criteria is limited to structures constructed using normal-weight concrete. Use of FRP bars in structural members for structures assigned in Seismic Design Categories C through F is permitted when following conditions are met: (1) structural members are not considered part of the lateral force-resisting system, (2) structural members are not required to be designed to accommodate drifts and forces that occur as the building responds to a seismic event.

In addition, the scope of this criteria is to allow FRP bars used in reinforced concrete elements complying with ACI 440.11 in Types I, II, III, IV and V construction. Where evaluation of fire-resistance-rated construction is sought, compliance with Section 4.8 is required.

1.3 Codes and Referenced Standards:

1.3.1 2021, 2018, 2015, 2012 and 2009 *International Building Code*® (IBC), International Code Council.

1.3.2 2021, 2018, 2015, 2012 and 2009 *International Residential Code*® (IRC), International Code Council.

1.3.3 ACI Code 318-19 (2021 IBC): ACI Code 318-14 (2018 and 2015 IBC); ACI 318-11 (2012 IBC), or ACI 318-08 (2009 IBC), Building Code Requirements for Structural Concrete and Commentary, American Concrete Institute.

1.3.4 ACI 408R-03 (reapproved 2012), Bond and Development of Straight Reinforcing Bars in Tension, American Concrete Institute.

1.3.5 ACI SPEC 440.5-22, Construction with Glass Fiber-Reinforced Polymer Reinforcing Bars - Specification, American Concrete Institute.

1.3.6 ACI Code 440.11-22, Building Code Requirements for Structural Concrete Reinforced with Glass Fiber-Reinforced Polymer (GFRP) bars – Code and Commentary, American Concrete Institute.

1.3.7 ASTM C904-01 (2012), Standard Terminology Relating to Chemical-Resistant Nonmetallic Materials, ASTM International.

1.3.8 ASTM D570-98(2010)e1, Standard Test Method for Water Absorption of Plastics, ASTM International.

1.3.9 ASTM D792-13, Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement, ASTM International.

1.3.10 ASTM D2584-18, Standard Test Method for Ignition Loss of Cured Reinforced Resins, ASTM International.

1.3.11 1.3.9 ASTM D3171-15, Standard Test Methods for Constituent Content of Composite Materials, ASTM International.

1.3.12 ASTM D4475-02(2008), Standard Test Method for Apparent Horizontal Shear Strength Of Pultruded Reinforced Plastic Rods by the Short-Beam Method, ASTM International.

1.3.13 ASTM D7205/D7205M-21, Standard Test Method for Tensile Properties of Fiber–Reinforced Polymer Matrix Composite Bars, ASTM International.

1.3.14 ASTM D7617/D7617M-11 (2017), Standard Test Method for Transverse Shear Strength of Fiber–Reinforced Polymer Matrix Composite Bars, ASTM International.

1.3.15 ASTM D7705/D7705M-12 (2019), Standard Test Method for Alkali Resistance of Fiber–Reinforced Polymer (FRP) Matrix Composite Bars Used In Concrete Construction, ASTM International.

1.3.16 ASTM D7913/D7913M-14, Standard Test Method for Bond Strength of Fiber-Reinforced Polymer Matrix Composite Bars to Concrete by Pullout Testing, ASTM International.

1.3.17 ASTM D7914/D7914M-14, Standard Test Method for Strength of Fiber Reinforced Polymer (FRP) Bent Bars in Bend Locations, ASTM International.

1.3.18 ASTM D7957/D7957M-22, Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement, ASTM International.

1.3.19 ASTM E1356-08 (2014), Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry, ASTM International.

1.3.20 ASTM E1640-18, Standard Test Method for Assignment of the Glass Transition Temperature by Dynamic Mechanical Analysis, ASTM International.

1.3.21 ASTM E2160–04 (Reapproved 2018), Standard Test Method for Heat of Reaction of Thermally Reactive Materials by Differential Scanning Calorimetry, ASTM International.

2.0 DEFINITIONS

For definitions of terms used in this criteria, refer to ASTM C904. Additional specific terms are defined as follows:

2.1 Production Lot:

FRP bar produced from start to finish with the same constituent materials used in the same proportions without changing any production parameter, such as cure temperature or line speed.

2.2 Guaranteed Property:

Characteristic value no greater than the mean minus three standard deviations of at least the required number of samples tested according to a specific test method. This definition is applicable to tensile strength and ultimate tensile load of the FRP bars.

2.3 Mean Property:

A value no greater than the mean of at least the required number of samples tested according to this criteria. This definition is applicable to tensile elastic modulus, moisture absorption, resistance to alkaline environment, shear strength (perpendicular to the bar), bond strength, and tensile strength of bent bars.

2.4 Surface Enhancement:

Protrusions, lugs, sand coatings, deformations or any additional surface treatment for purposes of inhibiting longitudinal movement of the bar relative to the concrete surrounding the bar in construction. The lugs, protrusions, sand coating and other enhancements are included in the measured cross-sectional area and affect the cross-sectional area of the FRP bar.

2.5 Measured Cross-Sectional Area:

The measured cross-sectional area of a bar including surface enhancement shall be determined in accordance with Section 4.1.3 of this criteria. The term “measured” reflects a true measured value as opposed to the term “nominal,” defined in Section 2.6 of this criteria, which indicates an equivalency.

2.6 Nominal Properties:

The nominal properties are used for the purpose of classification and design.

2.6.1 Nominal Cross-Sectional Area:

The nominal cross-sectional area of the FRP bar is determined based on the measured cross-sectional area within a tolerance range as given in Table 3 of ASTM D7957. This tolerance accommodates any enhancing surface treatment and is higher for smaller diameter bars.

2.6.2 Nominal Diameter:

The nominal bar diameter is the standard diameter as specified in Table 3 of ASTM D7957 for FRP bars, irrespective of the manufactured bar shape and form.

2.6.3 Nominal Bar Designation:

Admissible nominal bar designation number corresponds to the nominal diameter between 0.25 inch (No. 2) to 1.25 inches. (No. 10) (6.3 to 31.7 mm) in increments of $^1/_8$ inch (3.2 mm) for the nominal bar diameter as specified in Table 3 of ASTM D7957.

2.6.4 Nominal Guaranteed Tensile Strength:

The nominal guaranteed tensile strength is the ratio of the guaranteed tensile force and the nominal cross-sectional area.

2.7 Materials and Manufacture:

2.7.1 Fibers:

Fibers shall be in the form of unidirectional glass or basalt fiber rovings of given size and mass. Fiber sizings and coupling agents shall be compatible with the resin system used to impregnate the fibers. The fiber type and the fiber volume determine the physical and mechanical properties of the FRP bar.

2.7.2 Matrix Resin:

2.7.2.1 Thermo-set resin systems or their blending, excluding polyester resins, are permitted, provided the finished product meets the physical and durability requirements of this criteria. All other resin systems are outside the scope of this criteria.

2.7.2.2 The amount of styrene, as a mass percentage of the polymer resin, added during processing (if any) shall be reported.

2.7.3 Fillers and Additives:

2.7.3.1 Only inorganic fillers, such as kaolin clay, calcium carbonate, and alumina trihydrate, are permitted to be added to the polymer resin, and shall not exceed 20 percent by mass of the polymer resin.

2.7.3.2 Only additives and process aids, such as release agents, low-profile shrink additives, initiators, promoters, hardeners, catalysts, pigments, fire retardants, and ultraviolet inhibitors, are permitted to be added to the polymer resin.

2.7.4 Manufacturing Process:

2.7.4.1 FRP bars under this criteria are to be manufactured using variations of the pultrusion process or some other suitable process.

2.7.4.2 The manufacturer shall document the process used and report the date of production and the production lot size.

2.7.5 FRP Bar Shapes:

2.7.5.1 FRP Bent shape: an FRP reinforcing bar bent to a prescribed shape.

2.7.5.2 FRP Closed continuous stirrup/tie: an FRP bent shape fabricated as a continuous loop without end-joints.

2.7.5.3 FRP spirals: continuously wound FRP reinforcement in the form of a cylindrical or polygonal helix.

3.0 REQUIRED INFORMATION

3.1 General: The following information shall be submitted to ICC-ES for evaluation:

3.1.1 Product Description:

Product description shall include:

1. If applicable, restrictions or limitations on use.

2. Element identifiers for each bar size, including (but not limited to) the following:

- Name of the FRP material (manufacturer's description).
- Bar shape.
- Measured bar area and measured maximum outside cross-sectional dimension.
- Nominal area, nominal diameter, and bar designation of equivalent FRP round solid bar as specified in Table 3 of ASTM D7957.
- For bent bars, the shape of the bend, the radius of the bend, the angle of the bends (i.e., the bend angle is defined as the deviation from the main axis of the bar), and the length of the legs.

3.1.2 Installation Instructions:

The installation instructions shall include reference to the specification covering reinforced concrete member construction using FRP reinforcing bars, including requirements sets forth in ACI SPEC 440.5-22.

3.1.3 Packaging and Identification:

A description of the method of packaging and field identification of glass and basalt FRP bars in the form of cut lengths and bent shapes. Identification shall be in accordance with the product identification provisions of the ICC-ES Rules of Procedure for Evaluation Reports and shall include the bar size.

3.2 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.

3.3 Test Reports:

Test reports shall comply with AC85.

3.4 Product Sampling:

Sampling of the FRP bars for tests under this criteria shall comply with Section 3.1 of AC85. Additional requirements outlined in Section 4.5 of this criteria shall also apply.

3.5 Qualification Test Plan:

A qualification test plan shall be submitted to and approved by ICC-ES staff prior to any testing being conducted.

4.0 TEST AND PERFORMANCE REQUIREMENTS OF FRP BARS

This section consists of the following subsections addressing evaluation/testing requirements and conditions of acceptance:

Section 4.1: physical properties of FRP bars (i.e., fiber mass content, mean glass transition temperature, total enthalpy of polymerization, mean degree of cure, mean cross-sectional area).

Section 4.2: mechanical properties of straight FRP bars (i.e., guaranteed ultimate tensile force, mean tensile modulus of elasticity, transverse shear strength, mean ultimate tensile strain, guaranteed bond strength).

Section 4.3: durability properties: which includes the mean moisture absorption and mean alkaline resistance.

Section 4.4: properties of bent shapes (i.e., guaranteed ultimate tensile force of bent portion of bar, and tensile force of straight portion of bent bar or mean horizontal shear strength of straight portion of bent bar).

Section 4.5: properties of continuous closed stirrups/ties and spirals.

Section 4.6: bond factor value.

Section 4.7: required number of test specimen repetitions for all noted properties listed in this criteria.

Section 4.8: fire-resistance rated construction.

Section 4.9: structural tests.

A summary of tests required and minimum number of test repetitions, and production lots to sample are shown in Table 1 of this criteria.

4.1 Physical Properties:

4.1.1 Fiber Mass Content:

The fiber mass content shall be measured in accordance with ASTM D2584 or ASTM D3171. The mean fiber mass content shall be derived from tests with the number of specimens indicated in Section 4.7 of this criteria. The sand coating or other surface enhancement that is not fiber nor resin shall not be part of the fiber content measurements, where applicable. The individual test results shall be reported for each bar size tested. Testing of all bar sizes is required.

Conditions of Acceptance: The fiber content of as-produced FRP bars shall meet the property limits in Table 2 of ASTM D7957.

4.1.2 Mean Glass Transition Temperature:

The mean glass transition temperature $(T_g)_g$ shall be measured on a coupon cut from the as-produced bars using the dynamic mechanical analysis (DMA) method in ASTM E1640 or differential scanning calorimetry (DSC) method in ASTM E1356. When using DMA, the coupons shall be extracted longitudinally from the exterior diameter of the bar having a thickness no less than half of the outer bar diameter (i.e., the center core of the bar shall not be used for this test). The mean T_g shall be derived from tests with the number of specimens indicated in Section 4.7 of this criteria. The individual test results shall be reported for each bar size tested. Testing shall be conducted for the smallest, intermediate, and largest size bars to be evaluated.

Conditions of Acceptance: The mean T_g shall meet the property limits in Table 1 of ASTM D7957 when using DSC method, or be equal to or more than 110°C (230°F) when using DMA method.

4.1.3 Mean Total Enthalpy of Polymerization (Total Heat of Reaction):

Total enthalpy of polymerization (total hear of reaction) testing in accordance with ASTM E2160 is required on the unreacted (neat) resin system used for the manufacturing of the FRP bars. This test enables measuring the degree of

cure as a percentage of the full cure and provides a reference value for durability tests.

The mean total enthalpy of polymerization shall be reported and be used to determine the degree of cure and for fingerprinting the material. The mean total enthalpy shall be derived from tests conducted on the neat resin with the number of specimens indicated in Section 4.7 of this criteria.

4.1.4 Mean Degree of Cure:

The mean degree of cure (fraction reacted) of as-produced bar shall be determined in accordance with ASTM E2160 as a percentage of the mean total polymerization enthalpy of the neat resin. The mean degree of cure shall be derived from tests conducted on samples extracted from segment of a slice of the cross-section of the solid bar with the number of specimens indicated in Section 4.7 of this criteria. The individual test results shall be reported for each specimen. Testing of all bar sizes is required.

Conditions of Acceptance: The mean degree of cure of as-produced FRP bars shall meet the property limits as Table 1 of ASTM D7957.

4.1.5 Mean Measured Cross-Sectional Area:

The measured cross-sectional area of the FRP bar shall be obtained in accordance with Section 11.2.5.1 of ASTM D7205/D7205M and ASTM D792, Test Method A (volume of water displacement), accounting for any surface treatments. For hollow-core bars, water shall enter the intentional cavity. For all bar types, the specimen length shall be, as a minimum the smaller of twice the maximum measured outside cross-sectional dimension as per Section 4.1.4 or 2 in. (50 mm).

The mean measured cross-sectional area shall be derived from tests with the number of specimens indicated in Section 4.7. The individual test results shall be reported for each bar size tested. Testing of all bar sizes is required.

Conditions of Acceptance: Bars with mean measured cross-sectional areas within the ranges listed in Table 3 of ASTM D7957 are covered by this criteria. Additionally, when a bar has a measured cross-sectional area that falls outside the limits of two consecutive cross-sectional area ranges (identified here as the lower and higher ranges) and meets the minimum guaranteed tensile load (Table 3 of ASTM D7957) of the higher range, the bar can be classified under this criteria with the designation of the higher range.

4.2 Mechanical Properties:

The deviation of any strength value obtained from any single test shall not vary from the average value from all tests by more than 15 percent. If such deviation exceeds 15 percent, then additional sets of tests shall be performed until the deviation of any test does not exceed 15 percent from the average of all tested or a minimum of 15 additional tests have been performed.

4.2.1 Guaranteed Ultimate Tensile Force:

The ultimate tensile force for product certification shall be measured according to ASTM D7205/D7205M with the number of test specimens indicated in Section 4.7 of this criteria. For hollow-core bars, the terminations of the specimen to be inserted in the anchors will be plugged with appropriate material to prevent crushing of the FRP bar in the grip. The individual test results shall be reported for each bar size tested. Testing of all bar sizes is required.

Conditions of Acceptance: The guaranteed tensile force shall be calculated in accordance with Section 2.2 of this criteria. The minimum guaranteed tensile force shall meet the property requirement values listed in Table 3 of ASTM D7957 for bar designations 2 through 10. Others are outside the scope of this criteria.

4.2.2 Mean Tensile Modulus of Elasticity:

The tensile modulus of elasticity shall be derived from specimens tested in accordance with ASTM D7205/D7205M with the number of specimens as indicated in Section 4.7 of this criteria. For hollow-core bars, the terminations of the specimen to be inserted in the anchors will be plugged with appropriate material to prevent crushing of the FRP bar in the grip. The individual test results shall be reported for each bar size tested. Testing of all bar sizes is required.

Conditions of Acceptance: The mean tensile modulus of elasticity of FRP bars shall be the value reported by the manufacturer; and shall meet the property limit in Table 1 of ASTM D7957 regardless of bar size or shape.

4.2.3 Guaranteed Transverse Shear Strength:

The transverse (perpendicular to bar) shear strength shall be determined in accordance with ASTM D7617. For non-circular FRP bars, the portion of the specimen in contact with the fixture will have to be encased in an appropriate material in order to evenly distribute the applied load. The guaranteed transverse shear strength is determined with the number of specimens as indicated in Section 4.7 of this criteria. The individual test results shall be reported for each bar size tested. Testing of all bar sizes is required.

Condition of Acceptance: The guaranteed transverse shear strength of FRP bars shall be calculated in accordance with Section 2.2 of this criteria. The minimum guarantee transverse shear strength shall meet the property limits in Table 1 of ASTM D7957 regardless of bar size or shape.

4.2.4 Mean Ultimate Tensile Strain:

Based upon the assumption that the stress-strain behavior is linear-elastic, the ultimate tensile strain shall be calculated by dividing ultimate tensile force by the product of mean tensile modulus of elasticity and nominal cross-sectional area. The tensile strain obtained by this procedure shall be reported for each individual test and for all bar sizes with the number of specimens indicated in Section 4.7 of this criteria. Testing of all bar sizes is required.

Condition of Acceptance: The mean ultimate tensile strain shall meet the property limits in Table 1 of ASTM D7957 regardless of bar size or shape.

4.2.5 Mean Guaranteed Bond Strength:

The guaranteed bond strength (and load) of FRP bars (except closed continuous stirrups/ties or hoops) shall be determined In accordance with ASTM D7913 with the number of specimens indicated in Section 4.7 of this criteria. The individual test results shall be reported for each bar size tested, together with the method used for casting the test specimens. Testing shall be conducted for the

smallest, intermediate, and largest size bars to be evaluated.

Conditions of Acceptance: The guaranteed bond strength of any FRP bar type shall meet the property limits in Table 1 of ASTM D7957. Failure by full separation of the surface enhancement from the load bearing portion of the FRP bar is not acceptable.

4.3 Durability Properties

4.3.1 Mean Moisture Absorption:

Specimens shall be tested in accordance with ASTM D570, Section 7.1 and Section 7.4, at a temperature of 122°F (50°C) with the number of specimens as indicated in Section 4.7 of this criteria. The moisture absorption obtained by these procedures shall be reported for each individual test result. Testing of all bar sizes is required.

Conditions of Acceptance: After long-term saturation period, and 24-hour immersion period, the mean moisture absorption of as-produced FRP bars shall meet the property limits in Tables 1 and 2 of ASTM D7957, respectively. The average of the moisture absorption test results shall be less than 1.0 percent increase in mass when taken to saturation at ambient temperature. The 24-hour immersion shall result in less than 0.25 percent increase in mass at an elevated temperature of 122°F (50°C).

4.3.2 Mean Alkaline Resistance:

The resistance to alkaline environments shall be determined according to either Procedure A or B of ASTM D7705 with the number of specimens as indicated in Section 4.7 of this criteria. For both procedures, bars shall be exposed to alkaline solution for 90 days at a temperature of 140°F (60°C). For bars exposed to the alkaline solution and a sustained stress (ASTM D7705, Procedure B), the stress level shall correspond to a strain equal to 0.003. The individual test results shall be reported for each bar size tested. Testing shall be conducted for the smallest, intermediate, and largest size bars to be evaluated.

Conditions of Acceptance: For bars subject to the alkaline solution under no load (Procedure A), the mean post-exposure tensile force shall be equal or greater than 80 percent of the mean ultimate tensile force. For bars subject to a sustained stress (Procedure B), the mean post-exposure tensile force shall be greater than 70 percent of the mean ultimate tensile force.

4.4 Properties of Bent Shapes:

This section is only applicable to bent shapes obtained from bending solid FRP bars while the resin is not fully polymerized.

4.4.1 Bend Diameter:

The minimum inside bend diameter for any factory-formed FRP bar bend shall be as specified by the report applicant and shall meet Table 4 of ASTM D7957 for each bar designation. This minimum bend diameter requirement does not apply to bends where production technology allows the proper alignment (i.e., parallelism) of the fibers in the bend.

4.4.2 Guaranteed Ultimate Tensile Force of Bent Portion of Bar:

The ultimate tensile force of the bent portion of bars shall be determined in accordance with ASTM D7914. Number of specimens shall be as indicated in Section 4.7 of this criteria. The test laboratory shall report the individual test results and the test method. Testing shall be conducted for the smallest, intermediate, and largest size bars to be evaluated.

Conditions of Acceptance: The guarantee ultimate tensile force of the bent portion of a bar shall meet the property limits in Table 1 of ASTM D7957.

4.4.3 Tensile Strength of Straight Portion of Bent Bars:

When the bent size allows it, the tensile strength of the straight portion of the bent (leg) shall be measured according to ASTM D7205/D7205M with the number of test specimens indicated in Section 4.7 of this criteria.

When the bent (leg) size does not allow for the tensile testing, refer to Section 4.4.4. Testing shall be conducted for the smallest, intermediate, and largest size bars to be evaluated.

Conditions of Acceptance: The tensile load of the straight portion of the bent (leg) for every test shall meet the property requirement values listed in Table 3 as specified in ASTM D7957.

4.4.4 Mean Horizontal (Inter-Laminar) Shear Strength:

When the bent size does not allow for the tensile testing of one of its straight portions (leg) in accordance with Section 4.4.3, the horizontal (inter-laminar) shear strength of both the straight bars and specimens obtained from straight portion of bent bars shall be determined in accordance with ASTM D4475 and for fiber mass content of the bent portion in accordance with ASTM D2584, where the specimen shall be obtained from the geometric center of the bent. For non-circular FRP bars, the portion of the specimen in contact with the fixture will have to be encased in an appropriate material in order to evenly distribute the applied load. The horizontal shear strength and fiber mass content for bent bars is determined with the number of specimens as indicated in Section 4.5 of this criteria. The individual test results shall be reported for each bar size tested. Testing shall be conducted for the smallest, intermediate, and largest size bars to be evaluated.

Condition of Acceptance: The apparent horizontal shear strength of FRP bars when compared to the transverse shear strength of identical FRP bars shall be at least 25 percent for bar sizes No. 3 to No. 6 and 35 percent for bar sizes No. 7 to No. 10. Additionally, the mean horizontal shear strength of the straight portion of the bent bar shall be no less than 10 percent of the mean horizontal shear strength of the straight bar. The fiber content of bent specimen shall meet the conditions provided in Section 4.1.1 of this criteria.

4.5 Properties of Continuous Closed Stirrups/Ties and Spirals:

This section is only applicable to continuous closed stirrups/ties of any solid, polygonal or circular cross-sectional shape with or without surface enhancing treatments manufactured without end joints, that have been manufactured via a different process to the straight (longitudinal) bar.

4.5.1 Guaranteed Ultimate Tensile Force of Bend Portion of Bar:

Section 4.4.2 applies with identical conditions of acceptance.

4.5.2 Straight Portion Of Stirrups/Ties (Hoops):

For this test, the manufacturer shall produce: a) stirrups/ties such that the longest straight leg of the element can be extracted for characterization; or, b) straight bars of sufficient length using the identical constituents and production method of the stirrups/ties and spirals.

The straight portion of the stirrups/ties and spirals shall be treated as any straight bar for which physical properties (Section 4.1) and mechanical properties (Section 4.2), and durability properties (Section 4.3), shall be determined. Number of specimens shall be as indicated in Section 4.7.

Conditions of Acceptance: See Sections 4.1, 4.2 and 4.3.

4.6 Bond Factor:

The bond factor (K_b) is a design term that accounts for the degree of bond between FRP bars and concrete. The report applicant shall provide a bond factor value for the FRP bars. The K_b value shall be derived from experimental tests based on an approved qualification test plan. Alternatively, a conservative default value of 1.2 may be assumed and reported in accordance with ACI Code 440.11, Section 24.3.2.3.

4.7 Specimen Selection and Number of Specimens:

Tests exhibiting failure modes influenced by the test methodology, such as anchorage slip or influence of the anchorages on the free length of the specimen, shall be disregarded. Specimen selection and number of specimens shall comply with ASTM D7957.

4.8 Fire-Resistance-Rated Construction ~~and Noncombustibility Tests~~:

The use of the FRP reinforced concrete assemblies in fire-resistance-rated construction shall be evaluated in accordance with Section 703 of the IBC. ~~In addition, if evaluation is sought for other than Type V construction, FRP bars shall be evaluated for noncombustibility in accordance with Section 703 of the IBC.~~

Structural Tests

Structural concrete members internally reinforced with FRP bars other than round circular solid cross-section shall be tested in accordance with Annex A of this criteria to verify the design equations and assumptions to be used in the engineering analysis as given in ACI Code 440.11.

5.0 QUALITY CONTROL

5.1 Quality documentation complying with the ICC-ES Acceptance Criteria for Quality Documentation (AC10) shall be submitted for each facility manufacturing or labeling products that are to be evaluated in the ICC-ES evaluation report.

5.2 FRP bars shall be manufactured under an approved quality control program with inspections by an inspection agency accredited ICC-ES.

5.3 A qualifying inspection shall be conducted at each manufacturing facility in accordance with the requirements of the ICC-ES Acceptance Criteria for Inspections and Inspection Agencies (AC304).

6.0 FINAL SUBMITTAL

The final submittal shall include test reports, and a Design Manual (except for round circular GFRP bars). The latter is to be based on the design criteria presented in ACI Code 440.11. The final submittal shall also include all of the information listed in Sections 3.0 and 4.0 of this criteria.

6.1 Test Report:

Prior to testing, a test plan proposal shall be submitted to the ICC-ES. The independent laboratory shall report on certification testing performed according to the approved test plan. Besides the information requested in Section 4.0, the test report must include the following for any given production lot traceable to the identifying marking on the FRP straight bar and bundles, groups or shapes of bent bars tested:

- Sampling of test specimens in accordance with this criteria and AC85.
- Test date and laboratory where testing was performed.
- Production lot number or identifying marking.
- Specific product identification nomenclature used by the fiber manufacturer.
- Description of specimens tested (i.e., specimen length, free length, and anchorage details when applicable).
- Description of the testing method when the choice of more than one test method or variation has been specified in this criteria.
- Measured geometric properties: cross-sectional area and maximum outside cross-sectional dimension.
- Nominal bar area and diameter, bar designation and nominal tensile strength.
- Physical properties from tests: fiber content with indication of reference by mass or volume, glass transition temperature, and dimensions of bars not included in measured geometric properties.
- Guaranteed tensile loads for each diameter.
- Mean mechanical properties from tests: tensile modulus of elasticity, calculated ultimate tensile strain, transverse shear strength (perpendicular to the bar), bond strength, and (for solid bars only) strength of the bent portion of bars.
- Mean durability properties from tests: moisture absorption and resistance to alkaline environment.
- Descriptions of testing apparatus (i.e., load frame type and capacity, extensometer, data acquisition software, and other pertinent details).

7.0 EVALUATION REPORT REQUIREMENTS

The evaluation report shall include the following information:

7.1 A statement that design and installation must be in accordance with the published ICC-ES report, the approved quality documentation, ACI Code 440.11, the report

holder's Design Manual (when applicable), and the IBC and IRC.

7.2 A statement that structural design of concrete members strengthened with round circular solid GFRP bars must be in accordance with the ACI Code 440.11. BFRP bars, and GFRP bars other than round circular solid cross-section must be designed in accordance with the report holder's Design Manual, including the applicable statements in Section 8.0 of this criteria. Copies of quality documentation and the Design Manual must be submitted to the code official for each project using the systems, when requested.

7.3 A statement that complete construction documents, including plans and calculations verifying compliance with the evaluation report, must be submitted to the code official for each project at the time of permit application. The construction documents must be prepared and sealed by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed.

7.4 If there is testing in accordance with Section 4.~~6~~ 8 of this criteria, fire-resistance rating of the concrete assembly ~~and type of construction~~ shall be reported in the ICC-ES evaluation report based on test results. Otherwise, there must be a statement in the evaluation report that the fire-resistance rating of the FRP reinforced concrete assembly is outside the scope of the evaluation report, and concrete assemblies with FRP bars are limited to use where nonfire-resistance-rated construction is permitted by the IBC~~type VB construction under the IBC~~.

7.5 A statement that FRP bars shall be stored above the surface of the ground on platforms, skids, or other supports as close as possible to the point of placement. If stored outdoors, the FRP reinforcing bars shall be covered with opaque plastic or other types of cover that will protect the bars from ultraviolet rays.

7.6 A statement that special inspection as required by Table 1705.3 of the IBC for steel-reinforced concrete construction, is also applicable to FRP bar reinforced concrete construction.

7.7 A statement that application of FRP bars to be used in structural members for structures that are assigned in Seismic Design Categories C through F is permitted when following conditions are met: (1) structural members are not considered part of the lateral-force-resisting system, (2) structural members are not required to be designed to accommodate drifts and forces that occur as the building responds to a seismic event.

7.8 A statement that FRP bars used in reinforced concrete elements complying with ACI 440.11 may be used in Types I, II, III, IV or V construction in accordance with IBC Section 603.1, Item 20.

8.0 DESIGN CRITERIA AND DETAILING

8.1 Design Manual for BFRP Bars, or Bars Other Than Round Circular Solid Cross-section:

The report holder's dated Design Manual for BFRP bars, and GFRP bars other than circular solid cross-section shall be submitted to ICC-ES for review and be referenced in the ICC-ES evaluation report. The Design Manual shall include complete analysis and interpretation of the certification test results by showing sample calculations for the design and detailing of concrete members reinforced with FRP bars in accordance with ACI Code 440. The Design Manual shall list the nominal tensile strengths for each bar size obtained by tests under this criteria (see definition in Section 2.6.4), which shall be equal to or higher than the minimum nominal tensile strength values as listed in ASTM D7957. The Design Manual shall also present the nominal bar area as given in ASTM D7957 for the corresponding nominal tensile strength. The Design Manual shall also report the K_b value for each bar size as applicable, and specify how the overlap (splice) length for bars is determined.

The Design Manual shall include detailing examples for the structural applications the applicant is seeking evaluation for, and may include:

As a minimum, the design and detailing examples shall include:

- One-way slab.
- Two-way slab.
- Beam (flexure- and shear-controlled failures).
- Shallow foundation.
- Column.
- Wall.

8.2 FRP Creep Rupture and Fatigue:

The ICC-ES evaluation report or Design Manual (when applicable) shall indicate that, to account for potential failure of the FRP reinforcement due to creep rupture or fatigue, FRP stress at service shall be limited to 30 percent of the guaranteed and nominal tensile strength, respectively, for each set of design examples, in accordance with ACI Code 440.11, Section 24.6.2.

8.3 Concrete Member Cross-Section:

The ICC-ES evaluation report or Design Manual (when applicable) shall indicate that, for flexural and shear members, there is no restriction for the shape of concrete member cross-section (e.g., rectangular, T-shape, L-shape).

8.4 FRP Bar Arrangement:

The ICC-ES evaluation report or Design Manual (when applicable) shall indicate that, for flexural reinforcement, the use of multiple bar layers and bar bundling is permitted.

For multiple bar layers, the relevant provisions for steel reinforcing bar in ACI 318 also apply to FRP bars. Because FRP materials have no plastic region, the stress in each reinforcement layer varies depending on its distance from the neutral axis. Thus, the analysis of the flexural capacity shall be based on a strain-compatibility approach.

For bundled bars, all relevant provisions of ACI 318 apply.■

TABLE 1—SUMMARY OF TESTS FOR FRP BARS*

PROPERTY	TEST OR CALCULATION METHOD
Fiber mass content	ASTM D2584
Mean glass transition temperature	ASTM E1640 (DMA) ASTM E1356 (DSC)
Mean total enthalpy of polymerization (resin)	ASTM E2160
Mean degree of cure	ASTM D2160
Mean measured cross-sectional area	ASTM D7205/D7205M ASTM D792
Guaranteed ultimate tensile force	ASTM D7205/D7205M
Tensile modulus of elasticity	
Guaranteed transverse shear strength (⊥ to the Bar)	ASTM D7617
Mean horizontal shear strength (of straight bar)**	ASTM D4475
Guaranteed bond strength	ASTM D7913
Mean moisture absorption (24 hours)	ASTM D570
Mean moisture absorption to saturation	
Mean alkaline resistance	ASTM D7705 (A or B)
Guaranteed ultimate tensile force of bent portion of bar	ASTM D7914
Tensile force of straight portion of bent bar; or mean horizontal shear strength (// to the bar) of straight portion of bent bar; and fiber mass content of bend portion	ASTM D7205 or ASTM D4475 and ASTM D2584

* Specimen selection and number of specimens shall comply with ASTM D7957.
** Test applicable to straight portion of bent bars, refer to Section 4.4.4.

ANNEX A
ADDITIONAL QUALIFICATION TESTS FOR FRP REINFORCEMENT OTHER THAN ROUND SOLID FRP BARS

A1.0 Qualification Test Plan:

The intent of testing structural concrete members internally reinforced with FRP bars other than round circular solid bars, such as rectangular or hollow-core bars, shall be to verify the design equations and assumptions to be used in the engineering analysis. All or part of the tests described in this section, and any additional tests identified for special features of the product or system, shall be specified in a test plan submitted to, and approved by, ICC-ES staff for evaluation prior to testing. The minimum number of repetitions for full scale structural tests under this section for any condition tested shall be three specimens. The test plan shall be a complete document.

The limit state design capacities as determined in accordance with ACI Code 440.11-22 cannot exceed the five percent fractile values of the capacities obtained experimentally in accordance with Annex A.

Overall, qualification testing must provide data on material properties, force and deformation limit states, and failure modes, to support a rational analysis procedure. The specimens shall be constructed under conditions specified by the manufacturer, including curing. Tests must simulate the anticipated loading conditions, load levels, and deflections.

A2.0 Beams:

A2.1 Flexural Tests:

A2.1.1 Configuration: Beam spans shall be configured to induce flexural limit states or failure modes. Either simple or rigid supports are permitted. Extremes of dimensional, reinforcing, and compressive strength parameters shall be considered.

A2.1.2 Procedure: Loads may be monotonically applied. The limit states shall be determined based on material properties and an extreme concrete fiber compression strain of 0.003.

A2.2 Shear Tests:

A2.2.1 Configuration: Beam spans shall be configured to induce shear limit states or failure modes. Either simple or rigid supports are permitted. Extremes of dimensional, reinforcing, and compressive strength parameters shall be considered.

A2.2.2 Procedure: Loads may be monotonically applied. The limit states shall be determined based on material properties.

A2.3 Development Length Tests:

A2.3.1 Configuration: Beam splice specimens shown in Fig. B.1 represent larger-scale specimens designed to directly measure development and splice strengths in full-size members. Because of both its relative simplicity of fabrication and realistic stress-state in the vicinity of the bars, tests of spliced specimen has provided the bulk of the data used to establish the current design provisions for development length, as well as splice length, in ACI 318 (starting with ACI 318-95) as reported in ACI 408R-03. Beam spans shall be configured to induce flexural limit states or failure modes. Simple supports are permitted. Extremes of dimensional, reinforcing, and compressive strength parameters shall be considered.

A2.3.2 Procedure: Loads may be monotonically applied. The limit states shall be determined based on material properties.

A3.0 Slabs (Flexural Tests):

A3.1 Configuration: Slab spans shall be configured to include flexural limit states or failure modes. Either simple or rigid supports are permitted. Extremes of dimensional, reinforcing and compressive strength shall be considered.

A3.2 Procedure: Loads may be monotonically applied. The limit states shall be determined based on material properties and an extreme concrete fiber compression strain of 0.003.

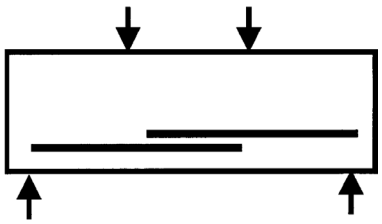

FIGURE B-1—DEVELOPMENT LENGTH TEST CONFIGURATION FOR FRP BARS