

# ACCEPTANCE CRITERIA FOR THE DEVELOPMENT OF PROPRIETARY DESIGN FORMULAE FOR FRP-REINFORCED GLUED-LAMINATED BEAMS

AC102

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## PREFACE

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

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

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

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

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

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

# ACCEPTENCE CRITERIA FOR THE DEVELOPMENT OF PROPRIETARY DESIGN FORMULAE FOR FRP-REINFORCED GLUED-LAMINATED BEAMS (AC102)

## 1.0 INTRODUCTION

**1.1 Purpose:** The purpose of this acceptance criteria is to establish requirements for development of proprietary design formulae for FRP-reinforced (fiber-reinforced polymer-reinforced) glued-laminated beams to be recognized in an ICC Evaluation Service, Inc. (ICC-ES), evaluation report under the [2006 International Building Code® \(IBC\)](#), the [2006 International Residential Code® \(IRC\)](#) and the [1997 Uniform Building Code™ \(UBC\)](#). Bases of recognition are IBC Section 104.11, IRC Section R104.11 and UBC Section 104.2.8.

The reason for the development of this criteria is to provide a guideline for derivation of proprietary design formulae for FRP-reinforced glued-laminated beams as IBC, IRC and UBC requirements.

**1.2 Scope:** This criteria establishes minimum guidelines for developing data necessary for the derivation of proprietary design formulae for FRP-reinforced glued-laminated beams. These guidelines include test requirements for both beam components and complete beams.

### 1.3 Codes and Reference Standards:

#### 1.3.1 Codes:

**1.3.1.1** [2006 International Building Code®](#), International Code Council.

**1.3.1.2** [2006 International Residential Code®](#), International Code Council.

**1.3.1.3** 1997 *Uniform Building Code™* (UBC).

#### 1.3.2 ASTM International Standards:

**1.3.2.1** ASTM D 198-99, Standard Test Methods of Static Tests of Lumber in Structural Sizes.

**1.3.2.2** ASTM D 143-94, Standard Test methods of Testing Small Clear Specimens of Timber.

#### 1.3.3 AITC (American Institute of Timber Construction) Standards:

**1.3.3.1** ANSI/AITC A 190.1-1992, Structural Glued Laminated Timber.

**1.3.3.2** [AITC 117-2004, Standard Specification for Structural Glued Laminated Timber of Softwood Species—Design Requirements—Standard Specifications for Structural Glued Laminated Timber of Softwood Species—Manufacturing Requirements, Structural Glued Laminated Timber.](#)

**1.3.3.3** [AITC 200-2004](#), Inspection Manual, Structural Glued Laminated Timber.

**1.4 Definitions: FRP-reinforced Glued-laminated Beam:** A structural member manufactured in accordance with AITC 117, ANSI/AITC A190.1 and AITC 200 in all details except for the use of laminates of proprietary fiber-reinforced polymers (FRP) in specific locations determined by tests and analysis.

## 2.0 BASIC INFORMATION

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

**2.1.1 Product Description:** Complete information concerning material specifications, thickness, size and the manufacturing process.

**2.1.2 Installation Instructions:** The installation and handling instructions shall include in-service requirements outlined in ANSI/AITC A190.1, AITC 117, and AITC 200.

**2.1.3 Packaging and Identification:** A description of the method of packaging and field identification of the fiber-reinforced glued-laminated beams. Identification provisions shall include the manufacturing layout combination, name of the beam fabricator, evaluation report number and the name or logo of the inspection agency.

### 2.1.4 Field Preparation:

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

**2.3 Test Reports:** Test reports shall comply with AC85.

**2.4 Product Sampling:** Products shall be sampled in accordance with Section 3.1 of AC85.

## 3.0 TEST AND PERFORMANCE REQUIREMENTS

**3.1 Adhesive Qualification:** Testing of specimens taken from full-scale test specimens shall be in accordance with AITC 200, except for the following:

**3.1.1 Sampling:** Adhesive spread measurement (AITC 200 Test T102) shall be conducted once for every 20 beams in the beam sample population.

**3.1.2 Test Requirements:** Adhesive species reinforcement combinations shall be qualified by strength and durability tests in accordance with AITC 200. A minimum of one sample of 15 or more specimens from each full-scale test beam shall be used for both shear and cyclic delamination testing. The shear test (AITC 200 Test T107) shall be conducted on samples subjected to one cycle of delamination testing.

**3.1.3 Test Conditions:** The specimens for delamination testing (AITC 200 Test T110) shall be subject to five cycles. Conditions of acceptance for delamination specified for one cycle apply to all five cycles for reinforcement-to-wood reinforcement-to-reinforcement joints.

**3.2 Reinforcement Qualification:** Fiber-reinforced plastic material used in the production of glued-laminated beams shall be tested for the properties listed below. A test program detailing specific test methods, conditions of testing, conditions of acceptance, and correlation to the design formulae shall be submitted to ICC-ES for approval.

**3.2.1** Tensile strength parallel to long axis of reinforcement.

**3.2.2** Compression strength parallel to long axis of reinforcement.

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**3.2.3** Compression strength perpendicular to long axis of reinforcement.

**3.2.4** Creep parallel to long axis of reinforcement.

**3.2.5** Thermal properties.

**3.2.6** Fatigue.

**3.2.7** Weathering.

**3.2.8** Physical properties including specific gravity void content, fiber content, dimensional tolerances, and mechanical properties.

**3.2.9** Ignition properties and smoke density.

**3.2.10** Thermal conductivity.

**3.2.11** Electrical properties.

**3.2.12** Wear resistance.

**3.2.13** Chemical resistance.

**3.2.14** Thermal expansion.

**3.2.15** Impact resistance.

### 3.3 Beam Qualification:

**3.3.1 General:** The following test program shall be conducted to verify derived design formulae. The number of test specimens in each size; layup combination; reinforcement type, concentration, and location, may be adjusted as test results are assessed and statistical assumptions established.

**3.3.2 Test Standard:** Testing shall comply with ASTM D 198.

**3.3.3 Test Specimens:** Test specimens shall be identified, including moisture content, wood laminations, method of conditioning, reinforcement type, location and thickness and type of adhesive. Beam layups shall conform to standard AITC layups specified in AITC 117.

**3.4 Flexural Testing:** Allowable flexural design properties shall be verified by the following test program:

#### 3.4.1 Moment (M) Design Series for Aramid Reinforced Polymer:

**3.4.1.1 General:** The reinforcement type, concentration, cross sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be full length and full width of the glued-laminated beam. The reinforcement shall be placed between the outer two laminations in the tension zone. The reinforcement type used shall be aramid reinforced polymer (ARP). The physical characteristics and strength properties of the ARP shall be monitored and documented with all test results.

**3.4.1.2 Visually Graded Douglas Fir, All L-1 Layup:** The following test specimens shall be manufactured using layup combination No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M1:** Twenty beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M2:** Three beams 2.5 inches (63.5 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M3:** Three beams 6.75 inches (171 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M4:** Three beams 5.125 inches (130 mm) by 24 inches (610 mm) by 42 feet (12 802 mm) with two layers of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M5:** Three beams 2.5 inches (63.5 mm) by 24 inches (610 mm) by 42 feet (12 02 mm) with two layers of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M6:** Three beams 6.75 inches (171 mm) by 24 inches (610 mm) by 42 feet (12 802 mm) with two layers of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M7:** Three beams 5.125 inches (130 mm) by 36 inches (914 mm) by 53 feet (16 154 mm) with three layers of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M8:** Three beams 6.75 inches (171 mm) by 48 inches (1219 mm) by 53 feet (16 154 mm) with eight layers of 0.07-inch-thick (1.8 mm) ARP (1.17 percent).

**Group M9:** Three beams 2.5 inches (63.5 mm) by 18 inches (457 mm) by 33.5 feet (10 211 mm) with two layers of 0.07-inch-thick (1.8 mm) ARP (0.758 percent).

**Group M10:** Three beams 6.75 inches (171 mm) by 36 inches (914 mm) by 53 feet (16 154 mm) with eight layers of 0.07-inch-thick (1.8 mm) ARP (0.97 percent).

**Group M11:** Three beams 8.75 inches (222 mm) by 48 inches (1219 mm) by 53 feet (16 154 mm) with eight layers of 0.150-inch-thick (3.8 mm) ARP (2.5 percent).

**3.4.1.3 Visually Graded Douglas Fir, All L-2 Layup:** The following test specimens shall be manufactured using layup combination No. 2, all L-2, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M12:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M13:** Three beams 2.5 inches (63.5 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M14:** Three beams 6.75 inches (171 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M15:** Three beams 5.125 inches (130 mm) by 24 inches (610 mm) by 42 feet (12 802 mm) with two layers 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M16:** Three beams 2.5 inches (63.5 mm) by 24 inches (610 mm) by 42 feet (12 802 mm) with two layers 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M17:** Three beams 6.75 inches (171 mm) by 24 inches (610 mm) by 42 feet (12 802 mm) with two layers 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**3.4.1.4 Visually Graded Douglas Fir, All L-3:** The following test specimens shall be manufactured using layup combination No. 1, all L-3, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

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**Group M18:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M19:** Three beams 2.5 inches (63.5 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M20:** Three beams 6.75 inches (171 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M21:** Three beams 5.125 inches (130 mm) by 24 inches (610 mm) by 42 feet (12 802 mm) with two layers 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M22:** Three beams 2.5 inches (63.5 mm) by 24 inches (610 mm) by 42 feet (12 802 mm) with two layers 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M23:** Three beams 6.75 inches (171 mm) by 24 inches (610 mm) by 42 feet (12 802 mm) with two layers 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**3.4.1.5 Visually Graded Hem-fir, All L-2:** The following test specimens shall be manufactured using layup combination No. 15, all L-2, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M24:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**3.4.1.6 Visually Graded Hem-fir, All L-1:** The following test specimens shall be manufactured using layup combination No. 16, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M25:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**3.4.1.7 Visually Graded Hem-fir, All L-1D:** The following test specimens shall be manufactured using layup combination No. 17, all L-1D, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M26:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**3.4.1.8 Visually Graded Southern Pine, All N-2D:** The following test specimens shall be manufactured using layup combination No. 48, all N-2D, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M30:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**3.4.1.9 Visually Graded Western Woods, All N-1D:** The following test specimens shall be manufactured using layup combination No. 50, all N-1D, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M31:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**3.4.1.10 E-rated Southern Pine, 2.3E-1/6:** The following test specimens shall be manufactured using layup combination No. 58, 2.3E-1/6, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M33:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**3.4.1.11 E-rated Douglas Fir, 2.3E-1/6:** The following test specimens shall be manufactured using layup combination No. 32, 2.3E-1/6, except for the outer tension zone. (See Table No. 2, AITC 117 "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M34:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**3.4.1.12 E-rated Western Woods 2.1E-1/6:** The following test specimens shall be manufactured using layup combination No. 44, 2.1E-1/6, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M35:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**3.4.2 Moment (M) Design Series for Carbon-reinforced Polymer (CRP) in the Tension Zone:** Visually graded Douglas fir, all L-1 layup will be used with this section of test specimens. The following test specimens shall be manufactured using layup combination No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117 "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M36:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) CRP (0.58 percent).

Further, the reinforcement type, concentration, cross-sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be full length and full width of the glued-laminated beam. The reinforcement shall be placed between the outer two laminations in the tension zone. The reinforcement type used shall be carbon-reinforced polymer (CRP). The physical characteristics and strength properties of the CRP shall be monitored and documented with all test results.

**3.4.3 Moment (M) Design Series for Fiberglass (E-glass) Reinforced Polymer (FRP) in the Tension Zone:** Visually graded Douglas fir, all L-1 layup, will be used with this section of test specimens. The following test specimens shall be manufactured using layup combination No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

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**Group M37:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) FRP (0.58 percent).

Further, the reinforcement type, concentration, cross-sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be full length and full width of the glued-laminated beam. The reinforcement shall be placed between the outer two laminations in the tension zone. The reinforcement type used shall be fiberglass (E-glass) reinforced polymer (FRP). The physical characteristics and strength properties of the FRP shall be monitored and documented with all test results.

**3.4.4 Moment (M) Design Series for Partial-length Reinforcement in the Tension Zone:** Visually graded Douglas fir, all L-1 layup will be used with the section of test specimens. The following test specimens shall be manufactured using layup combination No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M38:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.09-inch-thick ARP (0.58 percent), centered in 60 percent of the beam lengthwise [13 feet (3962 mm)].

**Group M39:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent), centered in 60 percent of the beam lengthwise [13 feet (3962 mm)].

**Group M40:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent), centered in 40 percent of the beam lengthwise [8.5 feet (2591 mm)].

Further, the reinforcement type, concentration, cross-sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be full length and full width of the glued-laminated beam. The reinforcement shall be placed between the outer two laminations in the tension zone. The reinforcement type used shall be aramid reinforced polymer (ARP). The physical characteristics and strength properties of the ARP shall be monitored and documented with all test results.

**3.4.5 Moment (M) Design Series for Reinforcement in the Compression and Tension Zone:** Visually graded Douglas fir, all L-1 layup, will be used with the section of test specimens. The following test specimens shall be manufactured using layup combination No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M41:** Ten beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the tension zone and one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the compression zone. Total reinforcement 1.16 percent by cross section.

Further, the reinforcement type, concentration, cross-sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be full length and full width of the glued-laminated beam. The reinforcement shall be placed between the outer two laminations in the tension zone. The reinforcement type used shall be aramid reinforced polymer (ARP) for tension zone and CRP for compression zone. The physical characteristics and strength properties of the ARP and CRP shall be monitored and documented with all test results.

**3.4.6 Moment (M) Design Series for Partial-length Reinforcement in the Tension and Compression Zone:** Visually graded Douglas fir, all L-1 layup, will be used with the section of test specimens. The following test specimens shall be manufactured using layup combination No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M42:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the tension zone, and one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the compression zone. Each centered in 80 percent of the beam lengthwise [17 feet (5182 mm)]. Total reinforcement shall be 1.16 percent by cross section.

**Group M43:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the tension zone and one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the compression zone. Each centered in 60 percent of the beam lengthwise [13 feet (3962 mm)]. Total reinforcement shall be 1.5 percent by cross section.

**Group M44:** Five beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) and one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the compression zone. Each centered in 40 percent of the beam lengthwise [8.5 feet (2591 mm)]. Total reinforcement shall be 1.5 percent by cross section.

Further, the reinforcement type, concentration, cross-sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be partial length (as shown below) and full width of the glued-laminated beam. The reinforcement shall be placed between the outer two laminations in the tension zone. The reinforcement type used shall be aramid reinforced polymer (ARP) for carbon reinforced polymer (CRP). The physical characteristics and strength properties of the ARP and CRP shall be monitored and documented with all test results.

**3.4.7 Moment (M) Design Series for Tension Face Reinforcement:** Visually graded Douglas fir, all L-1 layup, will be used with the section of test specimens. The following test specimens shall be manufactured using layup combination No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

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**Group M45:** Three beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M46:** Three beams 2.5 inches (63.5 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

**Group M47:** Five beams 6.75 inches (171 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent).

Further, the reinforcement type, concentration, cross-sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be full length and full width of the glued-laminated beam. The reinforcement shall be placed on the outside face of the tension zone. The reinforcement type used shall be aramid reinforced polymer (ARP). The physical characteristics and strength properties of the ARP shall be monitored and documented with all test results.

**3.4.8 Moment (M) Design Series for Tension and Compression Reinforcement:** Visually graded Douglas-fir, all L-1 layup will be used with this section of test specimens. The following test specimens shall be manufactured using layup combination No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M48:** Three beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) and one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the compression zone. Total reinforcement 1.16 percent by cross section.

**Group M49:** Three beams 2.5 inches (63.5 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the tension zone and one layer of 0.07-inch-thick (1.8 mm) CRP (0.58 percent) in the compression zone. Total reinforcement shall be 1.16 percent by cross section.

**Group M50:** Three beams 6.75 inches (171 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the tension zone and one layer of 0.07-inch-thick (1.8 mm) CRP (0.58 percent) in the compression zone. Total reinforcement shall be 1.16 percent by cross section.

Further, the reinforcement type, concentration, cross-sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be full length and full width of the glued-laminated beam. The reinforcement shall be placed in the outer face in the tension zone. The reinforcement type used shall be aramid reinforced polymer (ARP). In addition, compression reinforcement CRP shall be placed on the face of the outermost lamination in the compression zone. The reinforcement type used shall be aramid reinforced polymer (ARP) and carbon reinforced polymer (CRP). The physical characteristics and strength properties of the ARP and CRP shall be monitored and documented with all test results.

**3.4.9 Moment (M) Design Series for Partial-length Tension and Compression Reinforcement:** Visually graded Douglas fir, all L-1 layup, will be used with this section of test specimens. The following test specimens shall be manufactured using layup combination No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M51:** Three beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the tension zone and one layer of 0.07-inch-thick (1.8 mm) CRP (0.58 percent) in the compression zone. Total reinforcement shall be 1.16 percent by cross section. Each centered in 80 percent of the beam lengthwise [17 feet (5182 mm)].

**Group M52:** Three beams 2.5 inches (63.5 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the tension zone and one layer of 0.07-inch-thick (1.8 mm) CRP (0.58 percent) in the compression zone. Total reinforcement 1.16 percent by cross section. Centered in 60 percent of the beam lengthwise [13 feet (3962 mm)].

**Group M53:** Three beams 6.75 inches (171 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the tension zone and one layer of 0.07-inch-thick (1.8 mm) ARP (0.58 percent) in the compression zone. Total reinforcement 1.16 percent by cross section. Each centered in 40 percent of the beam lengthwise [8 feet (2438 mm)].

Further, the reinforcement type, concentration, cross-sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be partial length (as shown below) and full width of the glued-laminated beam. The reinforcement shall be placed on the outer face of the tension zone. The reinforcement type used shall be aramid reinforced polymer (ARP). In addition, compression reinforcement CRP shall be placed on the face of the outermost lamination in the compression zone. The reinforcement type used shall be aramid reinforced polymer (ARP) and (CRP). The physical characteristics and strength properties of the ARP shall be monitored and documented with all test results.

**3.4.10 Moment (M) Design Series for High Concentrations Tension and Compression Reinforcement:** The following test specimens shall be manufactured using layup combination No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group M54:** Three beams 5.125 inches (130 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with two layers 0.07-inch-thick (1.8 mm) ARP (1.16 percent) in the tension zone and two layers 0.07-inch-thick (1.8 mm) CRP (0.58 percent) in the compression zone. Total reinforcement shall be 2.32 percent by cross section.

**Group M55:** Three beams 2.5 inches (63.5 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with two layers 0.07-inch-thick (1.8 mm) ARP (1.16 percent) in the tension zone and two layers 0.07-inch-thick (1.8 mm) CRP

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(1.16 percent) in the compression zone. Total reinforcement shall be 2.32 percent by cross section.

**Group M56:** Three beams 6.75 inches (171 mm) by 12 inches (305 mm) by 21 feet (6401 mm) with two layers 0.07-inch-thick (1.8 mm) ARP (1.16 percent) in the tension zone and two layers 0.07-inch-thick (1.8 mm) CRP (1.16 percent) in the compression zone. Total reinforcement shall be 2.32 percent by cross section.

**Group M57:** Three beams 5.125 inches (130 mm) by 24 inches (610 mm) by 42 feet (12 802 mm) with eight layers 0.07-inch-thick (1.8 mm) ARP (2.33 percent) in tension zone and eight layers 0.07-inch-thick (1.8 mm) CRP (2.33 percent) in the compression zone. Total reinforcement shall be 4.66 percent by cross section.

**Group M58:** Three beams 2.5 inches (63.5 mm) by 24 inches (610 mm) by 42 feet (12 802 mm) with six layers 0.07-inch-thick (1.8 mm) ARP (1.75 percent) in the tension zone and six layers 0.07-inch-thick (1.8 mm) CRP (1.75 percent) in the compression zone. Total reinforcement shall be 3.50 percent by cross section.

**Group M59:** Three beams 6.75 inches (171 mm) by 24 inches (610 mm) by 42 feet (12 802 mm) with six layers 0.07-inch-thick (1.8 mm) ARP (1.75 percent) in the tension zone and six layers 0.07-inch-thick (1.8 mm) CRP (1.75 percent) in the compression zone. Total reinforcement shall be 3.50 percent by cross section.

Further, the reinforcement type, concentration, cross-sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be full length and full width of the glued-laminated beam. The reinforcement used in the compression zone shall be placed between the outer two laminations in the tension zone. The reinforcement type used in the tension zone shall be aramid reinforced polymer (ARP). The reinforcement used in the compression zone shall be placed between the outer two laminations in the compression zone. The compression reinforcement shall be CRP. The physical characteristics and strength properties of the ARP shall be monitored and documented with all test results.

**3.5 Shear Testing:** Allowable shear design properties shall be verified by the following test program: Shear (S) Design Series for Visually Graded Douglas-fir, all L-1 Layout: The following test specimens shall be manufactured using layup combination No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group S1:** Twenty beams measuring 5.125 inches (130 mm) by 24 inches (610 mm) by 15 feet (4572 mm) with a 10-foot (3048 mm) shear span; and one layer of ARP 0.07 inch thick (1.8 mm) (0.291 percent by cross-section concentration).

**Group S2:** Three beams measuring 5.125 inches (130 mm) by 24 inches (610 mm) by 15 feet (4572 mm) with a 10-foot (3048 mm) shear span; and two layers 0.07-inch-thick (1.8 mm) ARP (0.582 percent by cross-section concentration).

**Group S3:** Three beams measuring 5.125 inches (130 mm) by 24 inches (610 mm) by 15 feet (4572 mm) with a 10-foot (3048 mm) shear span; and three layers of

ARP 0.07 inch thick (1.8 mm) (0.875 percent by cross-section concentration).

**Group S4:** Three beams measuring 5.125 inches (130 mm) by 24 inches (610 mm) by 15 feet (4572 mm) with a 10-foot (3048 mm) shear span; and four layers of 0.07-inch-thick (1.8 mm) ARP (1.16 percent by cross-section concentration).

**Group S5:** Three beams measuring 5.125 inches (130 mm) by 24 inches (610 mm) by 15 feet (4572 mm) with a 10-foot (3048 mm) shear span. With no reinforcement to serve as a control.

**Group S6:** Three beams measuring 5.125 inches (130 mm) by 24 inches (610 mm) by 15 feet (4572 mm) with a 10-foot (3048 mm) shear span. With one layer of 0.07-inch-thick (1.8 mm) ARP (0.291 percent by cross-section concentration) in tension and one layer of 0.07-inch-thick (1.8 mm) CRP (0.291 percent) in the compression zone. Total reinforcement shall be 0.582 percent by cross section.

**Group S7:** Three beams measuring 5.125 inches (130 mm) by 24 inches (610 mm) by 15 feet (4572 mm) with a 10-foot (3048 mm) shear span. With two layers of ARP 0.07 inch thick (1.8 mm) (0.58 percent by cross-section concentration) in tension zone and two layers 0.07-inch-thick (1.8 mm) CRP (0.58 percent) in the compression zone. Total reinforcement shall be 1.16 percent by cross section.

**Group S8:** Three beams measuring 5.125 inches (130 mm) by 24 inches (610 mm) by 15 feet (4572 mm) with a 10-foot (3048 mm) shear span. With three layers of 0.07-inch-thick (1.8 mm) ARP (0.875 percent by cross-section concentration) in tension zone and three layers 0.07-inch-thick (1.8 mm) CRP (0.875 percent) in the compression zone. Total reinforcement shall be 1.75 percent by cross section.

**Group S9:** Three beams measuring 5.125 inches (130 mm) by 24 inches (610 mm) by 15 feet (4572 mm) with a 10-foot (3048 mm) shear span. With four layers of ARP 0.07 inch thick (1.8 mm) (1.16 percent by cross-section concentration) in tension zone and four layers 0.07-inch-thick (1.8 mm) CRP (1.16 percent) in the compression zone. Total reinforcement shall be 2.32 percent by cross section.

Further, the reinforcement type, concentration, cross-sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be full length and full width of the glued-laminated beam. The reinforcement shall be placed between the outer two laminations in the tension zone. The reinforcement type used shall be placed between the outer two laminations in the tension zone. The reinforcement type used shall be aramid reinforced polymer (ARP). The physical characteristics and strength properties of the ARP shall be monitored and documented with all test results.

**3.6 Deflection Testing:** Allowable deflection design shall be verified by the following test program:

**3.6.1 Deflection (D) Design Series for Visually Graded Douglas fir, all L-1 Layout Tension and Compression Reinforcement:** The following test specimens shall be manufactured using layup combination

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No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group D1:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and one layer of ARP 0.07 inch thick (1.8 mm) (0.291 percent by cross-section concentration) in tension zone.

**Group D2:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and two layers 0.07-inch-thick (1.8 mm) ARP (0.582 percent by cross-section concentration) in tension zone.

**Group D3:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and three layers of ARP 0.07 inch thick (1.8 mm) (0.873 percent by cross-section concentration) in tension zone.

**Group D4:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and four layers of 0.07-inch-thick (1.8 mm) ARP (1.16 percent by cross-section concentration) in tension zone.

**Group D5:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and no reinforcement to serve as a control.

**Group D6:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and one layer of 0.07-inch-thick (1.8 mm) ARP (0.291 percent by cross-section concentration) in tension and one layer of 0.07-inch-thick (1.8 mm) CRP (0.291 percent) in the compression zone. Total reinforcement shall be 0.582 percent by cross section.

**Group D7:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and two layers of ARP 0.07-inch-thick (1.8 mm) (0.58 percent by cross-section concentration) in tension zone and two layers 0.07-inch-thick (1.8 mm) CRP (0.58 percent) in the compression zone. Total reinforcement shall be 1.16 percent by cross section.

**Group D8:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and three layers of 0.07-inch-thick (1.8 mm) ARP (0.875 percent by cross-section concentration) in tension zone and three layers 0.07-inch-thick (1.8 mm) ARP (0.875 percent) in the compression zone. Total reinforcement shall be 1.75 percent by cross section.

**Group D9:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and four layers of ARP 0.07 inch thick (1.8 mm) (1.16 percent by cross-section concentration) in tension zone and four layers 0.07-inch-thick (1.8 mm) ARP (1.16 percent) in the compression zone. Total reinforcement shall be 2.32 percent by cross section.

Further, the reinforcement type, concentration, cross-sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be full length and full width of the glued-laminated beam. The reinforcement shall be placed between the outer two laminations in the tension zone. The reinforcement type used shall be aramid reinforced polymer (ARP) in the tension zone. CRP shall be used in the compression zone between the outer two laminations. The physical characteristics and strength properties of the CRP shall be monitored and documented with all test results.

### 3.6.2 Deflection (D) Design Series for Visually Graded Douglas Fir, all L-1 Layup, Reinforcement Placement Outside Face in Tension and Compression

**Zone:** The following test specimens shall be manufactured using layup combination No. 5, all L-1, except for the outer tension zone. (See Table No. 2, AITC 117, "Manufacturing Standard Specifications for Structural Laminated Timber of Softwood Species.")

**Group D10:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and one layer of ARP 0.07 inch thick (1.8 mm) (0.291 percent by cross-section concentration) in tension zone.

**Group D11:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and two layers 0.07-inch-thick (1.8 mm) ARP (0.58 percent by cross-section concentration) in tension zone.

**Group D12:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and one layer of ARP 0.07 inch thick (1.8 mm) (0.291 percent by cross-section concentration) in tension zone and one layer of 0.07-inch-thick (1.8 mm) CRP (0.291 percent) in the compression zone. Total reinforcement shall be 0.582 percent by cross section.

**Group D13:** Three beams measuring 5.125 inches (130 mm) by 12 inches (305 mm) by 36 feet (10 973 mm) with a 28-foot (8534 mm) shear span; and two layers 0.07-inch-thick (1.8 mm) ARP (0.58 percent by cross-section concentration) in tension zone and two layers 0.07-inch-thick (1.8 mm) CRP (0.58 percent) in the compression zone. Total reinforcement shall be 1.16 percent by cross section.

**Group D14:** Three beams measuring 8.75 inches (222 mm) by 42 inches (1067 mm) by 53 feet (16 154 mm) with a 45-foot (13 716 mm) shear span; and seven layers of 0.07-inch-thick (1.8 mm) ARP in the tension zone. Total reinforcement shall be 2.5 percent by cross section. Partial length center 32 feet of span (60 percent).

Further, the reinforcement type, concentration, cross-sectional location and placement longitudinally shall form the basis for reinforcement design criteria. The reinforcement in this test series shall be full length and full width of the glued laminated beam. The reinforcement shall be placed on the outer face of the tension zone when tension reinforcement is used and on the outer face of the compression zone when compression reinforcement is used. The reinforcement type used shall be aramid reinforced polymer (ARP) for tension and CRP for

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compression. The physical characteristics and strength properties of the CRP shall be monitored and documented with all test results.

**3.7 Compression Perpendicular-to-Grain Testing:** If higher load-bearing capacities than noted in ANSI/AITC 117, Standard Specification for Structural Glued Laminated Timber of Softwood Species Design, are sought, the allowable bearing capacity shall be verified by the test program described in Sections 3.7.1 through 3.7.3.2. Appropriate quality control procedures shall be included in the quality control manual.

**3.7.1 General:** A minimum of thirty specimens shall be tested for each combination of reinforcement type, concentration, and cross-sectional location, as well as for each combination of wood species and grade.

**3.7.2 Test Standard:** Testing shall comply with ASTM D 143.

**3.7.3 Test Specimens:** Test specimens shall be prepared and tested according to ASTM D 143-94, except for the following:

**3.7.3.1 Loading:** The load shall be applied through a metal bearing plate 2 inches (50 mm) in width, placed on the surface of the specimen that would correspond to the actual bearing surface of the beam. When the reinforcement is on the external face, the reinforcement shall be against the metal bearing plate, and when the reinforcement is in the internal placement, the bumper layer shall be against the metal bearing plate.

**3.7.3.2 Weight and Moisture Content:** The specimen does not have to be weighed before testing. The reinforcement shall be removed from the specimen before it is weighed immediately after the test. The moisture section shall be cut from the wood lamination that would correspond to the closest bearing surface of the beam.

**3.8 Test Conclusions:** Test results shall verify the proprietary formulae and limit the design formulae to species, reinforcement, and beam layups tested. The placement and concentration of reinforcement may be interpolated within the beam layups tested, using test results of beams with various locations and concentrations of reinforcement.

### 3.9 Other Considerations:

**3.9.1 Fire Resistance:** Beams requested to be recognized for fire performance shall be tested in accordance with ASTM E 119 and shall be rated for fire resistance in accordance with the results and conditions of such tests.

## 4.0 QUALITY CONTROL

**4.1** The products shall be manufactured under an approved quality control program with inspections by an inspection agency accredited by the International Accreditation Service (IAS) or otherwise acceptable to ICC-ES.

**4.2** Quality documentation complying with the ICC-ES Acceptance Criteria for Quality Documentation (AC10) shall be submitted.

## 5.0 EVALUATION REPORT RECOGNITION

The following Conditions of Use shall be inserted in the evaluation report:

**5.1** Design of the reinforced glued-laminated wood beams complies with this report and the applicable code. Calculations showing compliance with this report and the applicable code are submitted to the code official for review and approval.

**5.2** Installation of the FRP-reinforced glued-laminated wood beams complies with this report and the applicable code.

**5.3** Design procedures apply to beams loaded predominantly in bending.

**5.4** FRP reinforcement is not permitted to be notched or cut.