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# Load and Resistance Factor Design (LRFD) for Pultruded Fiber Reinforced Polymer (FRP) Structures

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# PREFACE

This standard is intended for use in the design of new buildings and other structures constructed of pultruded fiber–reinforced polymer (FRP) composite structural shapes, connections, and prefabricated building products. This standard does not cover tendons and cables. The standard applies to pultruded FRP structural shapes that have symmetric and balanced glass reinforcement and fiber architecture combined with a polymeric matrix. This standard was prepared by the Fiber Composites and Polymers Standards (FCAPS) committee of the Codes and Standards Activities Division of the Structural Engineering Institute of ASCE.

This standard is limited in its applicability to pultruded FRP composite shapes that utilize glass fiber reinforcement. The provisions were developed to apply to buildings and other structures; thus, the scope of the provisions resembles the scope of ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. Fiber–reinforced polymer structural systems, members, and components may be highly sensitive to their service environments. The registered design professional is advised to ascertain that the provisions and material constants herein apply to the structural component or system in their service environment under consideration.

The design strength and stiffness values provided in this standard apply to new structural products that are being placed into service for the first time. The standard provisions may not apply to structural products that may have been put into service prior to approval of the standard by ASCE.

This standard is intended for use by licensed engineers, structural engineers, architects, other professionals licensed in design of particular structures, and design professionals.

The LRFD pre-standard was developed by a select committee of authors for ASCE and sponsored by American Composites Manufacturers Association (ACMA) and member companies of the Pultrusion Industry Council (PIC). ASCE was tasked to assemble authors to write the required chapters and commentary for the standard. A project team (PT) of authors was selected based on knowledge and experience in this technology. Dr. Mehdi Zarghamee, Simpson Gumpertz & Heger Inc., was selected to serve as the project coordinator during this project. In addition to the PT, ASCE selected a volunteer Project Advisory Committee (PAC), who reviewed and commented on the pre-standard at various stages. The ACMA and the Pultrusion Industry Council (PIC) organized an LRFD Technical Committee of volunteer industry engineers, and technical and manufacturing experts.

The project team (PT) of authors for the LRFD pre-standard are as follows:

- Bruce Ellingwood, Ph.D., P.E., Georgia Institute of Technology – Chapters 1: General Provisions, and 2: Design Resistance
- Abdul-Hamid Zureick, Ph.D., Georgia Institute of Technology – Chapter 4: Compression Members and Bearing
- Hota GangaRao, Ph.D., P.E., West Virginia University – Chapter 3: Tension Members and Chapter 6: Members Under Combined Loads
- Larry Bank, Ph.D., P.E., F.ASCE, University of Wisconsin at Madison – Chapter 5: Members in Bending and Shear and Chapter 8: Joints and Connections
- Jack Lesko, Ph.D., Virginia Polytechnic Institute and State University – Chapter 7: Plates

We wish to also recognize several individuals who contributed to the development and review of the LRFD Pre-Standard:

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In the final publication of the LRFD, we wish to recognize the focus, dedication, and commitment of the following chapter lead authors to develop the chapters in this standard.

Chapter 1 – General Provisions – Bruce Ellingwood, Ph.D., P.E.
Chapter 2 – Design Requirements – Bruce Ellingwood, Ph.D., P.E.
Chapter 3 – Design of Tension Members – Hota GangaRao, Ph.D., P.E.
Chapter 4 – Design of Compression Members – Abdul-Hamid Zureick, Ph.D.
Chapter 5 – Design of Members for Flexure and Shear – Abdul-Hamid Zureick, Ph.D. and Mehdi S. Zarghamee, Ph.D., P.E.
Chapter 6 – Design of Members Subjected to Combined Forces and Torsion – Hota GangaRao, Ph.D., P.E.
Chapter 7 – Design of Plates and Built-up Members – Roberto A. Lopez-Anido, Ph.D., P.E.
Chapter 8 – Design of Bolted Connections – J. Toby Mottram, Ph.D.
Chapter 9 – Seismic Design Requirements – James R. Harris, Ph.D., P.E.

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# CHAPTER 1
# GENERAL PROVISIONS

This chapter establishes the scope of the standard and its design basis; summarizes referenced specifications and standards; and provides general requirements for materials, contract documents, fabrication, and quality assurance.

## 1.1 SCOPE

**1.1.1 Applicability and Exclusions** This standard is intended for use in the design of new buildings and other structures constructed of pultruded fiber–reinforced polymer (FRP) composite structural shapes, connections, and prefabricated building products. This standard does not cover tendons and cables. The standard applies to pultruded fiber-reinforced polymer (FRP) structural shapes that have symmetric and balanced glass reinforcement and fiber architecture combined with a polymeric matrix. The design of pultruded FRP structural shapes containing fibers other than glass shall be established in accordance with Section 2.3.2.

**1.1.2 Maximum Service Temperature** The maximum service temperature for pultruded FRP structural members, components, and systems designed according to this standard shall not exceed $T_g - 40$ °F ($T_g - 22$ °C), in which $T_g$ is the glass transition temperature of the composite system determined in accordance with ASTM E1640.

**1.1.3 Units** Where the provisions of this standard require units, they are provided as US customary units, with SI units provided either parenthetically or as footnotes to tables. Many of the equations presented do not require explicit statement of units; in these equations the designer shall use units for all quantities that are consistent.

## 1.2 REFERENCE STANDARDS, SPECIFICATIONS, AND CODES

The following standards, specifications, and codes are referenced in this standard.

ACI 318-19 Building code requirements for structural concrete
ANSI/AISC 360-16 *Specification for Structural Steel Buildings*
ASCE 7-16 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*
ASTM A307-14 *Standard Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength*
ASTM A436-84(20) *Standard Specification for Austenitic Gray Iron Castings*
ASTM A563-15 *Standard Specification for Carbon and Alloy Steel Nuts*
ASTM C581-15 *Standard Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service*
ASTM C666-15 *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing*
ASTM D570-18 *Standard Test Method for Water Absorption of Plastics*
ASTM D578-18 *Standard Specification for Glass Fiber Strands*
ASTM D638-14 *Standard Test Method for Tensile Properties of Plastics*
ASTM D696-19 *Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between –30 °C and 30 °C with a Vitreous Silica Dilatometer*
ASTM D790-17 *Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials*
ASTM D883-20 *Standard Terminology Relating to Plastics*
ASTM D907-15 *Standard Terminology of Adhesives*
ASTM D953-19 *Standard Test Method for Pin-Bearing Strengths of Plastics 2019*
ASTM D1144-16 *Standard Practice for Determining Strength Development of Adhesive Bonds*
ASTM D2343-17 *Standard Test Method for Tensile Properties of Glass Fiber Strands, Yarns, and Rovings Used in Reinforced Plastics*
ASTM D2344-16 *Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates*
ASTM D2583-13 *Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor*
ASTM D3878-19 *Standard Terminology of High-Modulus Reinforcing Fibers and Their Composites*
ASTM D3917-15 *Standard Specification for Dimensional Tolerance of Thermosetting Glass-Reinforced Plastic Pultruded Shapes*
ASTM D4385-19 *Standard Practice for Classifying Visual Defects in Thermosetting Reinforced Plastic Pultruded Products*
ASTM D5379-19 *Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method*
ASTM D5766-18 *Standard Test Method for Open-Hole Tensile Strength of Polymer Matrix Composite Laminates*
ASTM D6641-16 *Standard Test Method for Determining the Compressive Properties of Polymer Matrix Composite Laminates Using a Combined Loading Compression (CLC) Test Fixture*
ASTM D7136-15 *Standard Test Method for Measuring the Damage Resistance of a Fiber-reinforced Polymer Matrix Composite to a Drop-Weight Impact Event*
ASTM D7290-17 *Standard Practice for Evaluating Material Property Characteristic Values for Polymeric Composites for Civil Engineering Applications*